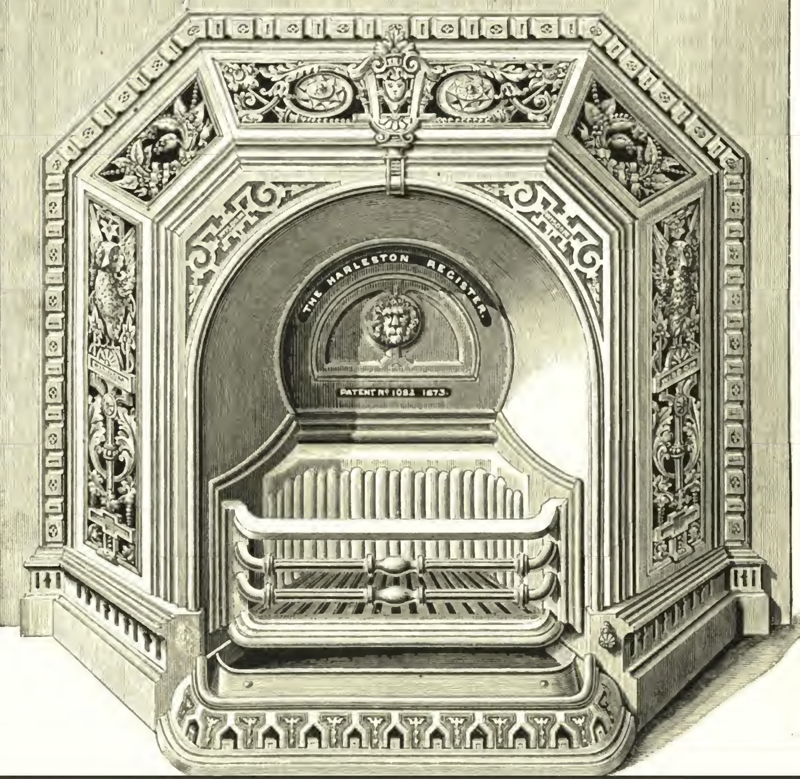


Report of the smoke abatement committee 1882

Smoke Abatement Committee (London, England), Daniel Kinnear Clark

LIVET & CO., LTD.

SOLE PROPRIETORS OF

LIVET'S & WERY'S PATENTS

FOR

IMPROVED

BOILER-FLUES, FURNACES, & FUNNELS

(Adaptable to all Boilers, old and new),

Have made arrangements to supply at Short Notice

LAND & MARINE BOILERS

Fitted

OR TO RE-SET EXISTI

Effecting grea

STEAM POW

UNLIMITED DRAUG

INDESTRI

ANY

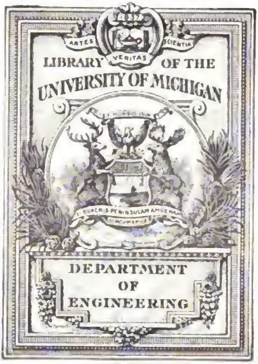
NO MECHANIS

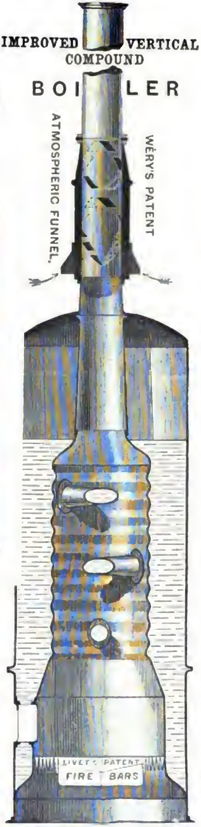
HIGH

S

SMOKE ABAT

Partic





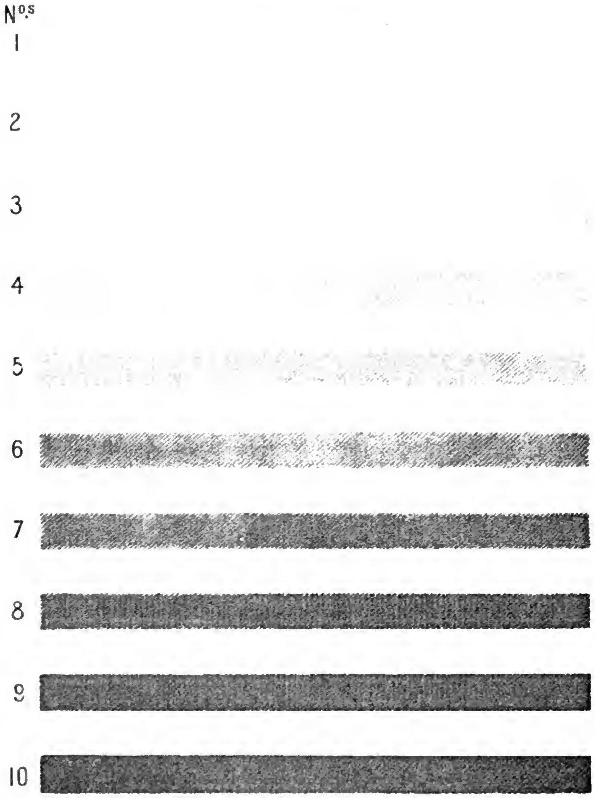
N.B.—The Boilers have practically no contact with Brick-work underneath, but rest on IRON SADDLES, and thus every rivet is open to inspection.

2 SHORT STREET, FINSBURY, E.C.

SMOKE SCALE.

employed in the Testings at the

SMOKE ABATEMENT EXHIBITION, 1882.



REPORT

OF THE

SMOKE ABATEMENT COMMITTEE, London

1882

WITH REPORTS OF THE JURORS OF THE EXHIBITION AT SOUTH KENSINGTON, AND REPORTS OF THE TESTING ENGINEER

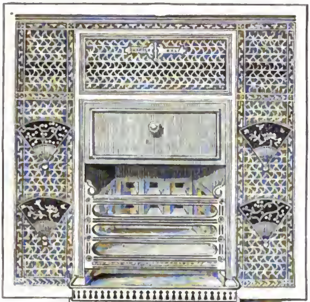
TO WHICH ARE ADDED

THE OFFICIAL REPORTS ON THE MANCHESTER EXHIBITION

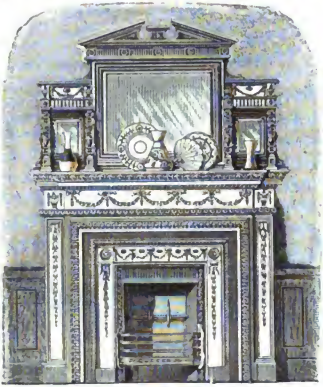
AND

76 PLATES OF ILLUSTRATIONS, AND 34 TABLES OF RESULTS OF TESTS OF HEATING AND COOKING-GRATES AND STOVES, STEAM-BOILER APPLIANCES, FUELS, &c.

LONDON
SMITH, ELDER, & CO., 15 WATERLOO PLACE
1883



Patent No. 1585.



PATENT IRON OVERMANTELS.

☞ See pp. 54 & 57.

Rechns, 4-24-43 D.

THE

SMOKE ABATEMENT COMMITTEE.

Presidents.

H.R.H. PRINCE LEOPOLD, DUKE OF ALBANY, K.G.
HIS GRACE THE DUKE OF WESTMINSTER, K.G.

18 Jy 05 G.S.

Committee.

Chairman—ERNEST HART, Esq.

PROF. ABEL, C.B., F.R.S., Royal Arsenal, Woolwich.
THE RIGHT HON. LORD ABERDARE, P.C., F.R.G.S.
A. T. ATCHISON, Esq., M.A.
WYNTER BLYTH, Esq., F.C.S., M.O.H., Marylebone.
LADY BORTHWICK.
SIR ANTONIO BRADY, F.M.S., F.G.S.
SIR F. J. BRAMWELL, F.R.S., V.P. Inst. C.E., Chairman of Council of the Society of Arts.
DR. ALFRED CARPENTER.
E. CHADWICK, C.B.
WM. R. E. COLES, Esq., C.E.
W. COOK, Esq., Chairman of the Health Committee, Birmingham.
THOMAS CUNDY, Esq.
T. W. CUTLER, Esq., F.R.I.B.A.
W. EASSIE, Esq., C.E.
DR. FARQUHARSON, M.P.
COLONEL E. R. FESTING, R.E., Science and Art Department, South Kensington.
PROF. EDWARD FRANKLAND, LL.D., F.R.S., School of Mines, South Kensington
CAPTAIN DOUGLAS GALTON, C.B., D.C.L., F.R.S.
GEORGE GODWIN, Esq., F.R.S.
FRANCIS GREG, Esq., Manchester.
VISCOUNT HARBERTON.
VISCOUNTESS HARBERTON.
R. HARRIS, Esq. (Gas Light and Coke Co.)
MISS OCTAVIA HILL.
R. A. HILL, Esq., Royal Mint.
DR. HOGG, LL.D., F.L.S.
ELIJAH HOOLE, Esq.
MISS EMILY SHAW LEFEVRE.
SIR FREDERICK LEIGHTON, P.R.A.
J. NORMAN LOCKYER, Esq., F.R.S.
D. H. MACFARLANE, Esq., M.P., M.A.
R. FULLER MAITLAND, Esq.
MRS. MALLET.
CHARLES T. MITCHELL, Esq.
B. L. MOSELY, Esq.
J. F. MOULTON, Esq., M.A., F.R.S.
SIR PHILIP CUNLIFFE OWEN, K.C.M.G., C.I.E., C.B.
C. KEGAN PAUL, Esq.
RIGHT HON. LYON PLAYFAIR, C.B., M.P., F.R.S.
SIR WM. FREDERICK POLLOCK, BART.
MISS POTTER.
PROF. W. CHANDLER ROBERTS, F.R.S., Royal Mint.
THE HON. ROLLO RUSSELL.
MAJOR-GENERAL H. Y. D. SCOTT, C.B., F.R.S.
SIR UGHTRED KAY-SHUTTLEWORTH, BART.
DR. SIEMENS, D.C.L., F.R.S.
H. SAXON SNELL, Esq., F.R.I.B.A.
DR. SPRENGEL, F.R.S.
E. STATHAM, Esq.
DR. TRIPE, F.R.C.P., M.O.H., Hackney.
ERNEST TURNER, Esq.
SIR H. HUSSEY VIVIAN, M.P.
J. LOWRY WHITTLE, Esq., Temple.
DR. WYLD.
LIEUT.-COLONEL H. STUART-WORTLEY, Curator of Patent Office Museum.
MISS H. YORKE.

Executive Committee.

F. A. ABEL, C.B., F.R.S. Royal Arsenal, Woolwich.
A. T. ATCHISON, Esq., M.A.
WM. R. E. COLES, Esq., C.E.
Colonel E. R. FESTING, R.E. Science and Art Department, South Kensington.
Prof. EDWARD FRANKLAND, LL.D., F.R.S. School of Mines, South Kensington.
Captain DOUGLAS GALTON, C.B., F.R.S.
Prof. W. CHANDLER ROBERTS, F.R.S., Royal Mint.
Sir UGHTRED KAY-SHUTTLEWORTH, Bart.
Dr. SIEMENS, D.C.L., F.R.S.
J. LOWRY WHITTLE, Esq., Temple.

Superintendent of Exhibition.

JAMES RICHARDS, Esq.

Testing Engineer.

D. KINNEAR CLARK, Esq., M.Inst.C.E.

Honorary Secretary to the Committee.

WM. R. E. COLES, Esq., C.E.

MANCHESTER EXHIBITION COMMITTEE.

Presidents.

H.R.H. PRINCE LEOPOLD, DUKE OF ALBANY, K.G.

HIS GRACE THE DUKE OF WESTMINSTER, K.G.

Committee.

Chairman—THE WORSHIPFUL THE MAYOR OF MANCHESTER.

THE RIGHT HON. THE EARL OF DERBY.
THE RIGHT HON. THE EARL OF ELLESMERE.
THE RIGHT REV. THE LORD BISHOP OF MANCHESTER.
THE RIGHT REV. THE BISHOP OF SALFORD.
SIR HUMPHREY DE TRAFFORD, BART.
JOHN SLAGG, ESQ., M.P.
J. BRIGHT, ESQ., M.P.
ARTHUR ARNOLD, ESQ., M.P.
F. W. GRAFTON, ESQ., M.P.
THE WORSHIPFUL THE MAYOR OF SALFORD.
THE WORSHIPFUL THE MAYOR OF OLDHAM.
THE WORSHIPFUL THE MAYOR OF STOCKPORT.
THE WORSHIPFUL THE MAYOR OF ASHTON-UNDER-LYNE.
THE WORSHIPFUL THE MAYOR OF ROCHDALE.
THE WORSHIPFUL THE MAYOR OF BOLTON.
MR. COUNCILLOR SCHOFIELD, Chairman of the Health Committee, Manchester.
MR. COUNCILLOR BATTY, Chairman of the Nuisance Committee, Manchester.
MR. ALDERMAN LAMB, Chairman of the Gas Committee, Manchester.
MR. COUNCILLOR GRIFFIN, Deputy-Chairman of the Nuisance Committee, Manchester.
MR. COUNCILLOR ROBERTS, Deputy-Chairman of the Markets Committee, Manchester.
MR. COUNCILLOR ROWLEY, Manchester.
MR. COUNCILLOR LEECH, Manchester.
MR. ALDERMAN DAVIES, J.P., Salford.
MR. ALDERMAN MCKERROW, J.P.
ARTHUR RANSOME, M.D., M.A., Chairman of the Manchester and Salford Sanitary Association.
DR. TATHAM, Officer of Health, Salford.
J. MAULE SUTTON, M.D., M.R.C.P. Lond. Officer of Health, Oldham.
OLIVER HEYWOOD, ESQ., J.P.
HERBERT PHILIPS, ESQ., J.P.
FRANCIS GREG, ESQ.
T. C. HORSFALL, ESQ.
ELLIS LEVER, ESQ.
S. L. HELM, ESQ.
J. G. COOPER, ESQ.
C. P. SCOTT, ESQ.
COLONEL SOWLER.
E. J. BROADFIELD, ESQ.
J. H. NODAL, ESQ.
HERBERT FLETCHER, ESQ.

Executive Committee.

Chairman—FRANCIS GREG, Esq.

HERBERT PHILIPS, Esq.
T. C. HORSFALL, Esq.
Rev. Canon WOODHOUSE, Esq.
Mr. Councillor ROBERTS.
ELLIS LEVER, Esq.
J. G. COOPER, Esq.
The Worshipful the MAYOR of SALFORD.
The Worshipful the MAYOR of OLDHAM.
Dr. SUTTON.
Dr. TATHAM.
JOSEPH CORBETT, Esq.
E. J. BROADFIELD, Esq.
JOHN LITTLEWOOD, Esq.
Rev. C. G. K. GILLESPIE.
C. ESTCOURT, Esq.
HERBERT FLETCHER, Esq.
Mrs. HARDIE.
Miss ROMLEY WRIGHT.
Miss WYNDHAM.
Mrs. FOARD.
Mrs. REDFORD.

Testing Engineer.

D. KINNEAR CLARK, Esq., M.Inst.C.E.

Secretary.

FRED SCOTT, Esq.

CONTENTS.

REPORT OF THE COMMITTEE.

REPORTS OF THE JURORS.

REPORTS OF THE TESTING ENGINEER.

MANCHESTER SMOKE ABATEMENT EXHIBITION—1882.

REPORT OF THE COMMITTEE.

REPORT OF THE JURORS.

REPORTS OF THE TESTING ENGINEER.

LIST OF TABLES.

MANCHESTER.

LIST OF ILLUSTRATIONS.

SMOKE ABATEMENT EXHIBITION, 1882.

REPORT OF THE COMMITTEE.

IN presenting the following series of Reports the Executive Committee would briefly direct attention to the labours that have preceded their own, and to the nature of the work they have endeavoured to continue.

Complaints as to the deleterious and obnoxious character of smoke evolved during the combustion of coal appear to have followed its gradual substitution for wood as fuel. Sir Hugh Platt, writing about the year 1594, was probably the first to suggest suitable admixtures of coal and other substances which gave less irritating smoke than coal alone. Evelyn's eloquent protest in his *Fumifugium*, printed in 1661, is well known, as is also his proposal 'that by an Act of the present Parliament this infernal nuisance (of smoke) be reformed.' Various attempts to abate the nuisance were made from time to time, perhaps the most important being that of Benjamin Franklin, who, in 1745, attacked the problem from the point of view of the domestic fire-place; while in 1795 James Watt, as is pointed out in the Report of the Jury on Fixed Boiler Appliances, suggested the use of smoke-consuming boiler furnaces in which cold fuel was introduced behind an incandescent mass.

In the hope of obtaining the most economical utilisation of heat, the question was investigated in the first decade of the present century by Count Rumford, who said that he never 'viewed from a distance the black cloud of unconsumed coal which hangs over London without wishing to be able to compute the immense number of chaldrons of coal of which it is composed.'

In 1819 the national importance of the smoke question was admitted in a very practical way by the appointment of a Select Committee of the House of Commons, 'to inquire how far persons using steam engines and furnaces could erect them in a manner less prejudicial to public health and comfort.' The Committee reported that 'so far as they had hitherto proceeded they confidently hope that the nuisance, so universally and so justly complained of, may at least be considerably diminished, if not altogether removed.' In 1843, another Select Committee 'inquired into the means and expediency of preventing the nuisance of smoke arising from fires or furnaces.' The list of witnesses examined by the Committee comprised the honoured name of Faraday, and, as their Report points out, 'they received the most gratifying assurances of the confident hope entertained by several of the highest scientific authorities examined by them that the same black smoke proceeding from fires and private dwellings, and all other places, may eventually be entirely prevented.' They concluded by recommending 'that a Bill should be brought into Parliament to prohibit the production of smoke from furnaces and steam engines.'

In May 1845 yet another Select Committee of the House reported 'that in the present state of knowledge and experience upon the subject, it is not desirable to extend the provisions of an Act beyond furnaces used for the generation of steam.' In August of the same year, Sir Henry de la Beche and Dr. Lyon Playfair reported to Lord Canning 'that it cannot for a moment be questioned that the continued emission of smoke is an unnecessary consequence of the combustion of fuel, and that, as an abstract statement, it can be dispensed with.' They add, however, 'it is useless to expect, in the present state of our knowledge, that any law can be practically applied to the fire-places of common houses, which, in a large town like London, contribute very materially to the pollution of the atmosphere.'

It is difficult now to realise a state of things, as regards the evolution of dense volumes of smoke from boiler furnaces, such as that described by the witnesses examined by the Parliamentary Committees, as the legal enactments which were the result of their labours did much to lessen the evils complained of. In the case, however, of domestic fire-places the question has remained without material change until the present day, although the rapid growth of the Metropolis materially adds to the gravity of the smoke nuisance.

The present effort to reduce the smoke nuisance is not directed exclusively to the suppression of smoke from the furnaces employed in factories or the fires of industrial works generally, as the object in view is the reduction of smoke from all sources, especially from dwelling-houses, the aggregate quantity of smoke from which is very considerable

The Committee are satisfied, as one result of their labours, that a large number of persons, representing all classes and interests, are now fully sensible of the importance of the subject, and, further, they find abundant and satisfactory evidence, in London and in the chief provincial towns, of anxiety to adopt any improved appliances for burning fuel, or any smokeless forms of fuel, when their merits have been fairly proved.

The Committee felt that, before attempting to stimulate and encourage inventors, manufacturers, and others to bring forward improved appliances, it was necessary to ascertain what the present state of our knowledge of the subject really is. The following series of reports mark the stage of progress already reached, and afford a firm basis for future work. The Committee have, therefore, directed the reports to be printed.

The origin of the present Smoke Abatement movement, dating from action taken by Mr. Ernest Hart in the National Health Society, and by Miss Octavia Hill in the Kyrle Society, has already been so fully set forth in the pages of the official catalogue of the Exhibition that it need form no part of this brief account of the Committee's aims and work.

The Smoke Abatement Exhibition may be said to have resulted from the several important public meetings which have marked the history of this movement, notably a public meeting at the Mansion House, summoned by the Smoke Abatement Committee, nominated jointly by the above Societies. This meeting was held on January 7, 1881, under the presidency of the Lord Mayor, when the Right Hon. G. J. Shaw-Lefevre, M.P., First Commissioner of Works, the late Dean of Westminster, Sir U. K. Shuttleworth, the President of the Royal Society, and others, eminent in literature, science, and art, addressed the meeting and supported the movement; a public meeting was held by the Kyrle Society, at which the President, H.R.H. the Duke of Albany, referred with warm approval to this movement as part of the Society's work, and a resolution in support of it was passed by the meeting. Shortly afterwards a largely-attended meeting was held at Grosvenor House, by permission of the Duke of Westminster, President of the National Health Society, at which H.R.H. the Princess Louise (Marchioness of Lorne) was present, when high scientific and medical evidence was borne by Dr. Siemens, F.R.S., Sir Henry Thompson, and Mr. Spencer Wells, to the importance of the question. The Committee then proceeded to complete arrangements, by the permission of Her Majesty's Commissioners for the Exhibition of 1851, the Lords

of the Committee of Council on Education, and of the Council of the Royal Horticultural Society, for an Exhibition to be held in the buildings erected for the International Exhibition of 1862, of improved fire-grates, furnaces, kitcheners, cooking, warming, and other apparatus of all kinds, devised to prevent smoke, or to consume smokeless fuel; the Exhibition to include varieties of bituminous and anthracite or smokeless coal, and special fuel for household fires and furnaces. In the catalogue, the various exhibits were classified and arranged under sections. Arrangements were also made for the fitting-up of some buildings for the purpose of testing the efficiency of grates, stoves, and other appliances suited for domestic use; and trials of various fuels and boiler appliances were also provided in the Exhibition Buildings and in the Royal Albert Hall, and at certain factories in which facilities were offered by the proprietors. It was resolved that the testing of apparatus should be made as far as possible under the following conditions:—

Tests of Apparatus and Fuels.

1. Domestic heating appliances—viz., grates, stoves, and kitcheners, and kitchen open ranges—to be tested for heating power, cost, convenience, quality of combustion, and their comparative freedom from smoke and noxious vapours. Various fuels and new appliances for the utilisation of anthracite and other smokeless coals to be tried. Gas heating-apparatus, in which great improvements have recently been made, to be tested and compared.

2. Furnaces and apparatus for industrial purposes, with which greater difficulty presents itself. Trials of some of the more recent improvements in boiler apparatus were to be made with the special object of testing the combustion of fuel and the prevention of smoke, having regard also to evaporative performance.

The Committee engaged the services of Mr. D. Kinnear Clark, M.Inst.C.E., to organise and conduct the tests, under the direction of the Executive Committee.

The Committee felt—and their view was confirmed by very numerous expressions of opinion, as a result of extended correspondence with persons of experience representing all classes in London, the provinces, and abroad—that such an Exhibition and testing, carried out under the direction of a Committee of Experts, would be of national value—

1. By tending directly to a better utilisation of coal and coal products.
2. By determining practically and scientifically the means which are actually available for heating houses, as at present (and as may be) constructed, without producing smoke.
3. By enabling the Committee to examine the subject generally, and report, for public information, upon the relative adaptability of the various coals and appliances to the different requirements of every class of the community.
4. By affording reliable information upon which to base sufficient and equitable amendments of the existing laws regarding smoke.
5. By enabling the Committee to ascertain and make known the comparative value of existing appliances for the utilisation of gas for the purpose of heating, and generally bringing together the available material for determining how far smoke may be prevented, and testing inventions but little known.

The Executive Committee, having been charged by the General Committee with the task of undertaking the details of arranging the Exhibition, Professor W. Chandler Roberts, F.R.S., drew up a scheme for the chemical testing in connection with the mechanical tests of grates and stoves. The Committee proceeded to communicate with the leading colliery proprietors and other persons connected with the production of coal and other fuel, and with the manufacturers of domestic grates, heating apparatus, stoves, &c.,

and also with the makers of boilers and furnaces for industrial purposes. Invitations to exhibit were widely sent out throughout the manufacturing districts of Great Britain, America, France, Germany, and other foreign countries, and communications explaining the objects were addressed to the municipal bodies of the principal towns interested. The Board of Trade was communicated with, and granted special protection to new inventions under the powers conferred upon them by the 'Protection of Inventions Act, 1870.' The assistance of foreign countries was sought, and with this view the aid of Earl Granville, the Secretary of State for Foreign Affairs, was solicited, and was most kindly and readily accorded. His Lordship forwarded particulars of the Exhibition, and directed communications to Her Majesty's representatives in France, Germany, Belgium, Sweden, and at the Hague and Copenhagen, with instructions to communicate with the Governments to which they were respectively accredited, and to request that publicity might be given to the objects of the Exhibition. By a later communication from his Lordship, the Exhibition Committee were informed that instructions had been directed to Her Majesty's representatives at Paris, Berlin, and Washington, to suggest to the Governments to which they are respectively accredited that a properly qualified person should be sent to report upon the Exhibition and the trials connected with it.

The Earl of Kimberley, the Secretary of State for the Colonies, also gave his assistance to the Exhibition Committee, by forwarding particulars of the Exhibition to the Governor-General of Canada, and further directed that certain inquiries should be made into the system of heating towns and villages by steam, in accordance with the request of the Smoke Abatement Committee.

The kind advice of Sir Philip Cunliffe Owen, and the assistance of Mr. G. R. Redgrave, and subsequently of Mr. James Richards, of the Royal Albert Hall, whose experience in matters relating to Exhibitions is well known, were obtained in making the necessary arrangements.

The formal opening of the Smoke Abatement Exhibition at South Kensington took place on November 30, 1881, when the Lord Mayor, who was accompanied by the Sheriffs and Under-Sheriffs, presided at a meeting held in the Albert Hall. There was a very large attendance of persons interested in the movement, including Her Royal Highness the Princess Louise (Marchioness of Lorne), and His Excellency the Marquis of Lorne, Governor-General of Canada, and other distinguished visitors. The meeting was addressed by His Excellency the Marquis of Lorne, the Right Hon. G. J. Shaw-Lefevre, M.P., Lord Aberdare, the Right Hon. H. Childers, M.P., Dr. Siemens, and others.

The Exhibition was primarily divided into two classes of appliances: applicable respectively to DOMESTIC and to INDUSTRIAL purposes. Objects exhibited in Sections A, B, and C were entirely for *domestic*, and those in Section D for *industrial* use. Section E was reserved for various fuels suitable for either domestic or industrial purposes, or both; and Section F for foreign exhibits of all classes.

Section letters were placed at the head of each page in the Official Catalogue, and an enumeration of the objects ranged under each Section was inserted at the head of such Section.

References were given under each entry to the locality of the exhibits, which were determined by the division of the galleries into measured blocks, which were distinguished by Roman numerals i. to xxvii.; beginning at the southern end of the Western Arcade (entrances in Queen's Gate), and ending at the southern end of the Eastern Arcade (entrances in the Exhibition Road).

The Exhibition included exhibits from the United States, France, Germany, Holland, Belgium, Sweden, and other countries; and for all domestic purposes a considerable number and variety of exhibits were shown, and chiefly in action. Special attention was directed to the industrial appliances, which included Smokeless Pottery Ovens and Gas Kilns, Dr. Siemens' Regenerative Gas Furnace, Gas Engines, and several applications of the principle of mechanical stoking to steam boilers, free from the disadvantage

of admitting cold air to the furnace. The production and application of combustible gases, other than ordinary coal gas, formed a prominent feature in the Exhibition.

With regard to fuels, anthracite, the smokeless and semi-bituminous coals of South Wales, and the bituminous coals of Northumberland and other districts were both exhibited and shown in use. Patent fuels were also exhibited.

Various systems of Electric Lighting were shown, together with the special appliances necessary for developing electricity. Also the Siemens' Electric Furnace and Electric Railway.

The object of the Exhibition being to encourage improvements, the Committee, so far as practicable, continued to admit suitable exhibits during the period of the Exhibition.

The endeavour was made to render the Exhibition instructive by demonstrations of the principle and mode of action of various machines and appliances, and exhibitors were afforded every reasonable facility in this respect, and abundant opportunity was furnished to them, at convenient times, for giving such explanations as might be necessary. Furnaces and machinery were, as far as practicable, shown in action.

The Exhibition was kept open at night at times which were advertised, and the following series of lectures on scientific matters connected with the objects of the Exhibition, and on the appliances themselves, were delivered from time to time :—

'Abatement of Smoke in relation to Heating and Ventilation,' by Captain Douglas Galton, C.B., F.R.S.

'The Abatement of Smoke,' by Mr. Ernest Hart.

'Waste in Combustion,' by Prof. Chandler Roberts, F.R.S.

'Smoke Abatement in connection with Glass and Pottery Burning,' 'Smokeless Baker's Ovens,' by Mr. W. J. Booer (Leeds).

'Economy of Fuel,' by Mr. F. Fletcher (Warrington).

'Lighting, Heating, and Ventilating,' by Mr. W. Sugg.

'The Effect of Coal-smoke upon the Human Organism,' by Dr. J. W. Fothergill.

'Varieties of Coal in relation to the question of Smoke Abatement, with special reference to the probable discovery of Coal at workable depths under London,' by Prof. Judd.

'Steam Boilers and the Prevention of Smoke,' by Mr. Holroyd Smith, M.I.M.E.

A course of popular readings: 'Improvements in Domestic Grates and Kitchen Ranges,' by Mr. E. J. Powell.

'Vitiated Air,' by Dr. Neale.

'Anthracite: its Uses and Economy,' by Mr. C. H. Perkins.

'Smokeless Baker's Ovens, and the Advantages of using Gas as a Fuel,' by Mr. W. J. Booer.

'Bread-Baking and Smokeless Ovens,' by Mr. William Lawrence.

Prizes and medals have been awarded to the best exhibits, and the arrangements under which these have been awarded are now made known. Among the liberal donors for this purpose is Dr. Siemens, who offered a Prize of 100 guineas. A Ladies' Prize of 100 guineas, divided into two sums for the best Domestic Open Grate and best Kitchener, was given. The Society of Arts offered a medal; the Manchester Association for Controlling the Escape of Noxious Vapours added a prize of 50*l.*; and further prizes were awarded.

The following is a list of the gentlemen who kindly undertook to act as Jurors:—

Prof. Abel, C.B., F.R.S.; Mr. A. T. Atchison, M.A.; Lord Alfred Churchill; Mr. Wm. R. E. Coles, C.E.; Mr. Thomas Cundy; Mr. T. W. Cutler, F.R.I.B.A.; Mr. W. Eassie, C.E.; Col. Festing, R.E.; Prof. Frankland, LL.D., F.R.S.; Capt. Galton, C.B.; Mr. R. Harris; Mr. Charles Heisch; Mr. Charles Hunt; Mr. T. W. Keates; Prof. Chandler Roberts, F.R.S.; Dr. Siemens, F.R.S., LL.D.; Mr. G. H. Trollope; Mr. Greville Williams, F.R.S. Mr. D. Kinnear Clark, M.Inst.C.E., Testing Engineer.

The Exhibition was formally closed on Tuesday afternoon (February 14) by a Meeting of Committee and Exhibitors, which was held in the Albert Hall, under the presidency of the Chairman, Ernest Hart, Esq. There was a large attendance of exhibitors and members of the Committee.

At this meeting it was announced that there had, up to the time of meeting, been made altogether 249 tests, many of them of a detailed and costly character: 27 tests of steam-boiler appliances, 42 tests of coal samples, 128 tests of open grates and stoves, and so on through the whole list. A great amount of work had been done, and done with great care, and special thanks are due to Dr. Siemens, Professors Frankland Abel, Roberts, Col. Festing, R.E., Mr. Atchison, Messrs. Harris, Heisch, Cutler, and the other Jurors, who have given gratuitously their best care and their most valuable time, in carrying out the work of the juries, as well as forwarding the objects of the Exhibition generally.

Among the distinguished visitors who attended the Exhibition and manifested great interest in the exhibits were H.R.H. the Prince of Wales, the Marquis of Lorne, the Empress Eugénie, and H.R.H. the Princess Louise, who honoured the Exhibition with two visits. The Duke of Westminster also visited the Exhibition and deputed Mr. Cundy (one of the jurors) to report to him on any appliances or new inventions or contrivances for existing grates which might be successfully introduced for the abatement of smoke in the houses on the Westminster estate. The Duke of Sutherland paid numerous visits to the Exhibition, as did other large landowners. The members of the House of Commons attended very numerously, and they had the satisfaction of receiving the Right Hon. G. J. Shaw-Lefevre, M.P. (First Commissioner of Works), who went very carefully into the details of what he had seen and gave instructions that a certain number of exhibits should be purchased for trial at the public offices. Among the visitors were deputies from the principal Foreign Governments—Monsieur Trélat, the eminent President of the Society of Civil Engineers in Paris, and Monsieur Hirsch, from the French Government; Dr. Gustav Wollf and Herr F. Siemens, from the German Government; Mr. John Hopkinson, F.R.S., Commissioner from the American Government; Monsieur H. Studer for the Swiss Government, and Commissioner for the Austrian Government. Those gentlemen will make reports on what they have seen here, so that the knowledge of the exhibits will extend to other countries. The Marquis of Lorne specially requested that a detailed account of the testing should be supplied to the Government of Canada.

At the meeting at the close of the Exhibition, due acknowledgment was made by the assembled exhibitors of the labours of the Committee.

Professor Abel proposed, on behalf of the meeting: 'That the best thanks of the meeting be given to Mr. Ernest Hart, the Chairman of the Committee, for the valuable services he has rendered to Smoke Abatement generally, and for the carrying of the scheme of this Exhibition to a successful issue.'

The Exhibition has been attended by the Royal Commissioners on Technical Education, the Institute of British Architects (who came in considerable numbers), the Institution of Civil Engineers (also in large numbers), the Institution of Mechanical Engineers, and the Members of the Coal and Iron Trades Institute. Also large deputations attended from builders and architects; and, in addition, the builders of London sent their workmen in large bodies. The Corporations of the various towns have shown great interest in this Exhibition, and a considerable number of the Mayors and other public officials attended personally; and further, the Corporations of Manchester, Birmingham, Sheffield, Oldham, and Leeds, sent official deputations, who have gone through the Exhibition, and who will make reports of a practical character, and present recommendations to their respective corporations. The following is a list of the Foreign Countries and Colonies represented by their deputies: France, Germany, United States, Switzerland, Austria, Hungary, Sweden, Denmark, the Netherlands, China, Canada,

and Australia. The total number of visitors to the Exhibition was 116,000; of these 46,000 were admitted by payment, and 70,000 persons to whom was given free admission.

The testing alone has involved an expenditure of about 1,000*l.*; for, besides the testings at South Kensington, extensive testings have been made elsewhere. 130 tests have been made of grates and stoves, 27 tests of coal-burning kitcheners, 32 tests of gas heating-apparatus, 20 tests of gas cooking-stoves, 4 tests of the Dowson Gas Producer and applications of the gas, 4 tests of heating apparatus, 27 tests of steam-boiler appliances, 1 test of a gas engine, and 45 tests of fuels; making the total number 290 tests. The Committee were very much indebted to the National Training School of Cookery, South Kensington, especially to Mrs. Charles Clarke, the lady superintendent, for sending her staff and assisting at practical trials of the kitcheners.

The exhibits have been thoroughly cited and illustrated in all the industrial papers.

As a result of the visit to the Exhibition of a deputation from the city authorities of Manchester, on Jan. 11, it was arranged to practically transfer the Exhibition, so far as it could be transferred, to Manchester, the Corporation having lent the market buildings for the purpose. To this end the Committee, its chairman, and its hon. secretary energetically co-operated. This Exhibition was opened on March 17, with an influential committee, consisting, among others, of the Earl of Derby, the Bishops of Manchester and Salford, Sir Humphrey de Trafford, Bart., &c., with the Mayor of Manchester as chairman, Mr. Francis Greg as chairman of the Executive Committee, and Mr. Fred. Scott as Secretary. It was thought desirable to connect the two exhibitions together, and H.R.H. Prince Leopold and the Duke of Westminster (the joint presidents of the South Kensington Exhibition) expressed their official approval of the step, by becoming presidents of this provincial Exhibition.

The testings at Manchester were conducted by Mr. D. Kinnear Clark on the same bases as those conducted at South Kensington, a separate report on which is appended. Medals have been awarded in accordance with these results.

The Manchester Exhibition closed on May 6. It proved highly successful, as shown by the Report of the Manchester Committee, appended.

The Committee trust that the opportunity which has been afforded by these Exhibitions of various appliances in action, and of improved fuels, and the trials carried on, will result in the extensive adoption by householders and manufacturers of the most successful and useful of the improvements shown, and that the impetus thus given to industrial energy and scientific ingenuity will bring about yet further improvements in the art and practice of heating, without unnecessary production of smoke. The Committee hope, also, that the Exhibitions have proved of advantage to many exhibitors who incurred no small amount of labour and expense in bringing their exhibits before the public in the way recommended by the Committee.

The following is the list of awards made in connection with the Smoke Abatement Exhibition at South Kensington; for details of which see the Jurors' Reports.

Open Grates for Bituminous Coal.—To Brown & Green (Under-fed Grate), gold medal; Clark, Bunnett & Co. (Ingram's Grate), silver medal; E. H. Shorland ('Manchester' Ventilating Grate, G. L. Shorland's patent), silver medal; E. R. Holland (Under-fed Grate), bronze medal; H. E. Hoole (Radiating and Reflecting Grate, with Side Hopper), bronze medal; M. Feetham & Co. (Basket Dog Grate), bronze medal; J. M. Stanley (Hopper-fed Grate), bronze medal; T. E. Parker ('Vencedor' Grate), bronze medal; W. I. Henry (Smoke Filtering Appliance), bronze medal; Doulton & Co. (Tile Grate), hon. mention; Rosser & Russell (Grate), hon. mention; Geo. Haller & Co. (Kohlhofer Hot-air Stove), hon. mention.

Open Grates for Smokeless Coal.—To the Coalbrookdale Co. ('Kyrle' Grate), silver medal; Yates, Haywood & Co. (Ventilating Grate), silver medal; Michel Perret (Grate), bronze medal.

Close Stoves for Bituminous Coal.—To C. B. Gregory (Stove), silver medal; John Cornforth ('Little Wonder'), silver medal; R. W. Crosthwaite (with Gregory's improvements), silver medal; J. F. Farwig & Co. (Stove), bronze medal; James Dunnachie (Stove), bronze medal; Rev. H. J. Newcombe (Stove), hon. mention.

Close Stoves for Smokeless Fuel.—To W. Barton (Stove), bronze medal; F. Lönholdt (Stove), bronze medal; Musgrave & Co. (Stove), H. J. Piron (Stove), bronze medal; Harry Hunt (Stove), bronze medal.

Kitcheners.—To T. J. Constantine, silver medal; Eagle Range Company, silver medal; Radiator Range Company, silver medal; Brown & Green, silver medal; Falkirk Iron Company, silver medal; Newton, Chambers & Co., bronze medal; W. Stobbs, bronze medal; M. Feetham & Co., bronze medal.

Gas Oven.—To Thompson Brothers, a gold medal for their patent kiln and baker's oven, being a distinctly new application of the use of coal gas, and one calculated to largely promote the abatement of smoke.

Gas Cooking-Stoves.—(A) Stoves suitable for families of about twelve persons.—To H. and C. Davis and Co., silver medal; to Beverley and Wylde, silver medal; J. Wright & Co., silver medal; Stark and Co., silver medal, in recognition of the principle adopted by them of burning the gas outside the oven in which the cooking is carried on; Billing and Co., bronze medal; Leoni and Co., bronze medal; C. Wilson, bronze medal; Waddell and Main, bronze medal. (B) Stoves suitable for large establishments; Slater and Co., for excellence of material and workmanship, silver medal.

Gas Heating-Stoves.—(C) Close stoves, from which the heat is conveyed into the apartment by conduction from pipes or chambers, through which the heated products of combustion pass.—To Stark and Co., for Cox's ventilating gas stove, a silver medal; the Sanitary and Economic Supply Association of Gloucester, for Dr. Bond's Euthermic ventilating stove (pattern A), a silver medal. (D) Open stoves or combination fires, in which gas is burned in combination with solid materials, and the heat radiated into the apartment.—Waddell and Main, for gas-and-coke fire (Dr. Siemens' principle), a bronze medal; G. Wright and Co., for gas-and-coke fire (Dr. Siemens' principle), a bronze medal. (E) Gas baskets or fires, from which the heat is conveyed by radiation.—To Leoni and Co., for hanging gas fire, a bronze medal.

Gas Producer.—To the Dowson Economic Gas Company, Limited, for their gas producer and the application of the gas to various industrial purposes, a gold medal.

Apparatus for Heating by Air, Water, and Steam.—To W. & S. Deards, bronze medal; W. Stainton, bronze medal.

Mechanical Stokers.—To George Sinclair, a silver medal; T. and T. Vicars, a silver medal; The Patent Steam-Boiler Company (Knap's stoker), a bronze medal; The Chadderton Ironworks Company (M'Dougall's stoker), a bronze medal; James Proctor, a bronze medal.

Fire-bridges.—To Chubb and Co., for their cast-iron semicircular fire-bridge, a bronze medal; Ireland and Lownds, for cast-iron tubular fire-bridge, a bronze medal.

Fire-bars and Fire-grates.—To the Wavish Patent Fuel Economiser Company, for the application of vertical grates in steam-boiler furnaces, a silver medal; J. Farrar and Co., for Barber's under-feeding stage grate, a bronze medal; J. Collinge, for Blocksage's external inclined grate, a bronze medal.

Furnace-door.—To W. A. Martin & Co., for a balanced fire-door, a bronze medal; the Great Britain Smoke-Consuming Company, a bronze medal.

Boiler Setting.—To Livet's Patent Improved Boilers and Furnace Company, for Mr. Fountain Livet's method of setting boilers, and his fire-bars, a silver medal.

Chimney.—To E. G. Wéry, Paris, for his atmospheric smoke-consuming chimney, a bronze medal.

Dr. Siemens' Prize of 100 guineas 'for the best method or arrangement for utilising fuel as a heating agent for domestic and industrial purposes combining the utmost economy and freedom from smoke and noxious vapours.'—The Dowson Economic Gas Company, 50 guineas; The Falkirk Iron Company, for their gas-and-coke-burning kitchener, 50 guineas.

Ladies' Prizes of 50 guineas, for kitchener and open grate.—Prize of 50 guineas divided between T. J. Constantine, for his 'Treasure' kitchener, and the Eagle Range Company, for their kitchener. For open grates, no award made.

Society of Arts Medal.—C. B. Gregory, of Beverley, New Jersey, U.S.A., for his smoke-burning furnace, and for its various applications to steam boilers and other industrial and domestic purposes.

The following is the list of awards made in connection with the Manchester Smoke Abatement Exhibition:—

Open Grates and Close Stoves.—T. E. Parker, for his smoke-preventing grate, being an improvement upon the grate exhibited by him in London, for which he was awarded a bronze medal, silver medal; Jaffrey & Co., for their smoke-consuming grate, being an improvement on the Kaio-Kapnos grate, which was awarded a silver medal in London, silver medal; J. Wadsworth, for his close ventilating stoves, burning coke and burning gas, silver medal; the Falkirk Iron Company, for improved coke-and-gas fire and asbestos-and-gas fire, modifications of Dr. Siemens' principle, silver medal; W. Thornburn, for his hot-air petroleum stove, honourable mention; E. H. Shorland, for the Manchester close stove (G. L. Shorland's patent), bronze medal; James Moore, for his system of boiler-seating with perforated bridges and steam-jets for the prevention of smoke and for economy of fuel, bronze medal; J. Hampton, for his fire-proof smoke-consuming bridge, bronze medal; B. Goodfellow, for Johnson's smoke-and-fume washer, honourable mention; Hydes & Wigfull, for the 'Tortoise' laundry stove, bronze medal.

Kitcheners and Cooking Stoves.—Elliott, Alston, and Olney, for Senking's cooking-stove, silver medal; R. W. Crosthwaite, for close-fire range, having Gregory's furnace, silver medal; Waddell & Main, for improved gas cooking-stove, silver medal; Charles Wilson, for impoved gas cooking-stove, silver medal.

Steam Boiler Appliances.—R. W. Crosthwaite, for Gregory's smoke-burning furnace, applied to an upright boiler, silver medal; E. Bennis, for his mechanical stoker, silver medal; Thomas Henderson, for his furnace-front and fire-door, bronze medal.

Furnace for General Heating Purposes.—Michel Perret, for his multiple-staged furnace, silver medal.

For details of the Awards see the following Reports of the Jurors.

19

REPORTS OF THE JURORS.

I. REPORT OF THE JURORS ON OPEN GRATES AND CLOSE STOVES.

THE class of grates and stoves was, as might have been expected, the largest in the Exhibition, and that in which there was the greatest difficulty in determining the relative merits of the different objects.

There were many well-considered efforts for diminishing the smoke from bituminous coal, and several examples of grates were shown in which endeavours were made to increase the efficiency of the fuel. Few of these, however, displayed any actual novelty. Grates and stoves for burning anthracite were well represented, and visitors thus had full opportunity of comparing, as far as is possible in an exhibition, the merits of smokeless coal and of appliances, in most cases involving some mechanical complication, for burning bituminous coal smokelessly; and the general impression must, we think, have been that, although the smoke difficulty is far from solution yet, a good deal of thought has been given to the matter, and that, attention having been now so much directed to it, there are hopes of still further improvement.

In recommending the awards that should be made, we have considered that one of the chief essentials of a grate or a stove should be that no noxious fumes should be given off into the apartment, and another—in the case of open fire-places—that there should be abundance of radiant heat. Subject to these considerations, we believe that apparatus to be most worthy of recognition in which the ratio of heating power to the amount of smoke produced is the greatest. Other considerations are: combination of heating with ventilation; economy of fuel and labour; simplicity of construction and of working; cheapness and durability; adaptability to existing arrangements; appearance; and these will doubtless influence purchasers considerably in their choice. But we are of opinion that—in determining our action as to awards in this—which is a Smoke Abatement Exhibition, and not an ordinary show of grates and stoves—these latter considerations should have small weight as compared with the main point of ratio of heating power to smoke given off. It is, therefore, on the results of the testings of heating power and visible smoke as carried out by Mr. Kinnear Clark, and of perfection of combustion as carried out by Professor Chandler Roberts, that our recommendations chiefly depend. We may remark that a careful examination of the tabulated results of these tests shows a substantial correspondence between the two sets.

The open grates are naturally divided according to whether they are fed (*a*) from the bottom or side, (*b*) from the top with an up-draught, (*c*) from the top with a down-draught; and, again, whether they are intended for bituminous or smokeless coal. The stoves, also, may be intended for bituminous or smokeless fuel.

Arnott's well-known stove, which has been in existence for half a century, was shown by F. Edwards & Son. The nearest to it in principle was that shown by the same exhibitors, in which the bottom of the grate is fixed, but the fuel burns downwards, and a counter-

balanced shutter in front of the bars determines the level at which air is admitted to the fire, and consequently that of active combustion. The results of the testing, however, were disappointing, as they showed that the fuel was not burnt to advantage, and considerable amount of smoke was produced.

Somewhat similar in principle are the hopper grates. The best results were given by those of H. E. Hoole and of J. M. Stanley, which we have recommended for bronze medals.

Of the arrangements for direct under-feeding, that of Brown & Green appeared to be the best, from a practical point of view; and it also gave the best results in the testing of any grates for bituminous coal. We have, therefore, recommended it for a gold medal.

E. R. Hollands' under-fed grate also gave fairly good results. There is some objection to the presence of mechanism in this grate, and we had no means of determining whether this would be liable to get out of order. The principle is, however, good, and we have recommended a bronze medal for this grate.

The system of under-feeding appears to be generally effective in reducing the amount of smoke, and, as the live coals are at the top, there is powerful radiation from it, which is not much reduced, as is the case in top-fed grates when fresh coal is put on.

The system of downward-draught with ordinary hand-feeding at the top is adopted in several grates, and in a few the results of the testing have been so satisfactory as to enable us to recommend awards; but we believe the system to be wrong in principle. The upper surface of the coal in the grate, and the back and cheeks of the fire-place, are necessarily cooled by the draught, and can radiate little or no heat to the room, and the combustion of the gases takes place in a position from which no heat can be radiated into the room. The heat derived from this portion of the combustion must, therefore, be wasted, unless it can be utilised to warm air or water, and so be distributed. Moreover, there were instances in the Exhibition where down or back-draught had produced rapid destruction of the bars, &c., of the grate; and, as so much of the combustion takes place out of sight, mischief may go on unnoticed.

With regard to the next subdivision, which may be said to include all ordinary grates, and in which the fuel is supplied at the top, and the draught is upwards, we would call particular attention to the pattern of a grate devised by Captain Douglas Galton, C.B., about twenty-two years ago, for use in barrack rooms, and adopted for that purpose by the War Office. On account of the position occupied by Captain Galton, with regard to the movement, this grate was not shown in competition, and was, therefore, not tested in the testing house, which is unfortunate, as it might at least have served as a standard of comparison, and we believe it to be certainly one of the most effective of the grates in the Exhibition. General Morin, in his well-known work on 'Heating and Ventilation,' states that in his experiments he found that, for a given quantity of coal, three times as much heat was utilised in the room, as in the case of any other open fire-place which he tried.

This economy of coal and consequent diminution of total smoke produced is effected principally by using what would otherwise be wasted heat at the back of the fire-place to warm fresh air, which is afterwards admitted to the apartment. The direct diminution of smoke also appears to be, to some extent, effected by arching the fire-brick back partly over the fire, thus forming a kind of baffle, underneath which heated air from behind the grate is introduced, to aid in the combustion of gases given off by the coal.

In no other grate are these two principles combined. The latter is more fully developed in Barnard, Bishop & Barnards' 'Glow fire;' but the results of the testing of this grate were not so satisfactory as to warrant the recommendation of an award.

Of the 'ventilating' grates in which the former principle is used, the best appeared to be E. H. Shorland's 'Manchester' grate for bituminous coal; that of Yates, Haywood & Co., for anthracite; and the 'Ingram' grate, shown by Clark, Bunnett & Co., which

gave satisfactory results both with Wallsend coal and anthracite; to each of which we have recommended the award of a silver medal.

An apparently very good ventilating grate was also shown by Robert H. Griffin, but, as this was not tested (we understand at the desire of the exhibitor), we have not been able to make any recommendation with regard to it.

We have recommended for 'honourable mention' G. Haller's Kohlhofer stove, which may be used as a ventilating grate, and Rosser & Russell's firebrick ventilating stove.

Of other open grates, we consider the best to be the Coalbrookdale Company's 'Kyrle' grate for anthracite, and M. Feetham & Co.'s basket dog-grate, for which we have proposed silver medals. The latter gave, with Wallsend coal, very good results as far as heating and visible smoke were concerned; but this was one of the few instances in which considerable efficiency was attained notwithstanding the somewhat incomplete combustion shown by the tests made by Professor Chandler Roberts. This grate has a down-draught. We have also recommended a bronze medal for T. E. Parker's 'Vencedor' grate, for the same reasons. It is, however, a little doubtful whether this should not have been placed in the class of stoves, as, although it has an open front, it stands clear of the chimney opening, thus giving off heat to the room from the back, top, and sides, as well as the front.

Michel Perret's grate for anthracite developed great heating power and radiation, the tests showing that the combustion of the fuel was fairly perfect. This grate is, as far as we know, a complete novelty. The recess of the fire-place is lined with firebrick at the sides, back, and top, a narrow slit of 2½ inches wide being left at the front edge of the top for the escape of the products of combustion. The fire is made in an open iron basket grate, set against the back of the recess, and supported on iron legs. The whole of the interior of the recess becomes very much heated, and there is a powerful radiation from it. A possible objection to this grate would seem to be that, under adverse circumstances, the products of combustion might be diffused into the apartment. This, however, we had no means of testing. We have considered it deserving of a bronze medal.

The principle of W. I. Henry's Smoke-purifyer is, we believe, novel. The grate was somewhat deficient in radiant power, but the arrangement for getting rid of smoke appeared to answer fairly well; and we have, therefore, recommended a bronze medal.

Among the close stoves the most remarkable was that exhibited by C. B. Gregory, of Beverley, New Jersey. In the form shown, it was, perhaps, rather more a 'furnace' than a stove applicable to domestic purposes. It was enclosed in a cubical casing of cast-iron, lined with firebrick. The fresh fuel is charged into a steeply inclined hopper of firebrick, and falls upon a horizontal grate. Air is admitted to the fuel at the lower part of the hopper, and through the grate. Air is also admitted at the front; it passes along the sides in contact with and heated by the hopper, and is discharged at the throat of the furnace in two streams from opposite sides, meeting and mingling with the half-burned gases from the fire. Complete combustion is thus effected. When tested with an hourly consumption of 21 lbs. of Wallsend coal, no visible smoke was produced, a result not attained by any other apparatus. Its heating power, as will be seen by a reference to the tables, was very great, too great, in fact, to be satisfactorily tested in the largest of the rooms at the disposal of the committee. R. W. Crosthwaite exhibited an Armstead's stove with Gregory's improvement, which gave excellent results. So did J. Cornforth's 'Little Wonder' stove, the bottom bars of which are hollow, air heated by passing through them being admitted at the back to support combustion and prevent the formation of smoke. For each of these three stoves we have recommended a silver medal.

J. F. Farwig & Co.'s 'Calorigen' stove and J. Dunnachie's 'Star' stove gave good results with bituminous coal, and we have recommended bronze medals for them.

Among the stoves for burning smokeless fuel there were two, that of Franz Lönholdt,

and the 'Crown Jewel' of Harry Hunt, both of which we have recommended for bronze medals, in which a somewhat novel feature, the 'base burning' arrangement, is introduced, which appears to give satisfactory results in improving the efficiency of the fuel. The former is also provided with a good automatic feeding arrangement, and the supply of the fuel can be so regulated that combustion is maintained with a very small expenditure, and the fire will burn for twenty-four hours or longer without attention. Visible smoke was, however, at times emitted during the tests, even when anthracite was used, and for this reason we have not considered it entitled to a higher award.

We have also recommended for bronze medals the 'Premier' stove of W. Barton, Musgrave & Co.'s well-known slow-combustion stove, and that of H. J. Piron, of Hodimont (Belgium).

A stove exhibited by the Rev. H. J. Newcome, in which the smoke is made to traverse horizontal iron pipes, and in which a considerable portion appears to be deposited as soot, and which impart heat to the room, gave results so far satisfactory as to entitle it to honourable mention.

We also recommend for honourable mention Doulton & Co.'s 'Tile' stove, which, though it has no special arrangements for getting rid of smoke, gave fairly good results in this respect, and was very efficient as regards heating power.

The following is the list of awards recommended in this section:—

LIST OF AWARDS.

Grates and Stoves.

(*a*) *Open Grates for Bituminous Coal.*

To Brown & Green, Luton, Beds., for Under-fed Grate, Gold Medal.

To Clark, Bunnett & Co., Rathbone Place, Oxford Street, for Ingram's Grate, which gives good results, both with Wallsend and Anthracite, Silver Medal.

To E. H. Shorland, St. Gabriel's, Manchester, for 'The Manchester Ventilating Grate,' G. L. Shorland's patent, Silver Medal.

To E. R. Hollands, Newington Green, London, for Under-fed Grate, Bronze Medal.

To H. E. Hoole, Sheffield, Radiating and Reflecting Grate, with Side Hopper, Bronze Medal.

To M. Feetham & Co., Clifford Street, London, for Basket Dog Grate, Bronze Medal.

To J. M. Stanley, Rhyl, for Hopper-fed Grate, Bronze Medal.

To T. E. Parker, Battersea Park, for 'Vencedor' Grate, Bronze Medal.

To W. I. Henry, for Reeve & Henry's Smoke-purifyer, Bronze Medal.

To Doulton & Co., Lambeth, for Tile Grate, Honourable Mention.

To Rosser & Russell, Charing Cross, for Fireclay Grate, Honourable Mention.

To George Haller & Co., Lime Street, for Kohlhofer Hot-Air Stove, Honourable Mention.

( ) *Open Grates for Smokeless Fuel.*

To The Coalbrookdale Company, Coalbrookdale, for 'Kyrle' Grate, Silver Medal.

To Yates, Haywood & Co., Upper Thames Street, for Back and Side Draught Ventilating Grate, Silver Medal.

To M. Perret, Paris, for Radiating Stove, Bronze Medal.

(*c*) *Close Stoves for Bituminous Coal.*

To C. B. Gregory, Beverley, New Jersey, for Smoke-Burning Furnace, Silver Medal.

To John Cornforth, Birmingham, for the 'Little Wonder' Stove, Silver Medal.

To R. W. Crosthwaite, Upper Thames Street (with Gregory's improvement), Silver Medal.

To J. F. Farwig & Co., Queen Street, London, for 'Calorigen' Stove, Bronze Medal.

To J. Dunnachie, Coatbridge, for Star Heating-Stove, Bronze Medal.

To Rev. H. J. Newcome, Barnet, for Air-Warming Stove, Honourable Mention.

(*d*) *Close Stoves for Smokeless Fuel.*

To W. Barton, Boston, for 'Premier' Gill Stove, Bronze Medal.

To Franz Lönholdt, Frankfort-on-the-Maine, for Anthracite Ventilating Stove, Bronze Medal.

To Musgrave & Co., Belfast, for Slow-Combustion Stove, Bronze Medal.

To H. I. Piron, Hodimont, Verviers, for Hot-Air Stove and Ventilator, Bronze Medal.

To Harry Hunt, Newington Green Road, for 'Crown Jewel' Stove, Bronze Medal.

For a description of each article that was tested in this section, and particulars of the results of the tests, see Mr. Clark's Report, page 46.

II. REPORT OF THE JURORS ON COAL-BURNING KITCHENERS.

THERE was considerable variety in the design of kitcheners burning coal, nineteen of which were submitted for testing. Several of them were specially designed for burning bituminous coal without smoke, others for burning anthracite, others for burning coke, with the aid of gas, and others were distinguished by special contrivances for economising fuel.

Referring to the report of Mr. Clark, the Testing Engineer, it appears that the conditions varied considerably for different kitcheners, with regard to dimensions as well as to capacity. Yet it is satisfactory to observe that the kitcheners which were the most economical in fuel were amongst the largest. Though Mr. Engert's and Brown & Green's kitcheners made the least smoke, in burning bituminous coal, they were not low in consumption of fuel. It appears to the jury that those exhibitors whose kitcheners combined most effectively the conditions of economy of fuel, low smoke-shade, and quality of work, were the following, to whom they recommend awards :—

LIST OF AWARDS.

KITCHENERS.

To T. J. CONSTANTINE, Fleet Street, for Treasury Range, a Silver Medal.

To THE EAGLE RANGE AND FOUNDRY COMPANY, Fleet Street, a Silver Medal.

To THE RADIATOR RANGE COMPANY, Cannon Street, whose kitchener is of novel design, and combines facilities for front-roasting in conjunction with oven-roasting, a Silver Medal.

To BROWN & GREEN, Luton, who adopt a novel method of under-feeding, with means of roasting in front, a Silver Medal.

To THE FALKIRK IRON COMPANY, Upper Thames Street, who adopted a novel modification of Dr. Siemens' system of gas-and-coke fire, for roasting and baking, a Silver Medal.

To NEWTON, CHAMBERS & Co., Sheffield, for their Thorncliffe Range, a Bronze Medal.

To W. STOBBS, Pimlico, for the Anthracite Range, a Bronze Medal.

To M. FEETHAM & Co., Clifford Street, for their W.F.S. Kitchener, a Bronze Medal.

For a description of each article that was tested in this section, and particulars of the results of the tests, see Mr. Clark's Report, page 96.

III. REPORT OF THE JURORS ON GAS COOKING-STOVES AND GAS HEATING-STOVES.

THE display of apparatus for the application of coal gas to cooking and heating purposes was very extensive and complete, not only reflecting great credit upon the exhibitors, but also proving to demonstration the great capabilities of coal gas as a substitute for solid fuel in the household, the workshop, and the manufactory. Especially is this of importance when it is remembered that no other kind of fuel can promise more for the abatement of smoke; none being so readily or even universally accessible, and at the same time, when properly used, so absolutely smokeless in its character, and convenient of application. To the public it will be of interest to know that the advantage of cleanliness and convenience may be largely secured, not only without pecuniary loss as compared with the cost of coal, but in many instances with positive gain.

For cooking purposes there were exhibited stoves of every size and capacity, from the small griller, suitable for cooking a simple chop, to the large roaster, adapted to the requirements of the most extensive establishments, the most numerous being stoves suitable for every-day use in families of about twelve persons, from which a selection was made for practical testing. As compared with previous gas exhibitions it was noteworthy that a considerable advance had been achieved, in style and finish no less than in completeness and adaptation to the varying necessities of the kitchen. For instance, with scarcely an exception, all the medium-sized cooking-stoves were adapted for grilling; this operation being effected upon the top, and by means of the same burners that are provided for boiling purposes; so that with an almost inappreciable consumption of gas a breakfast may be cooked in a very short space of time, and the labour and expense of fire-lighting altogether avoided. The trials of the cooking stoves were supervised by Mrs. Charles Clarke, the Lady Superintendent of the National Training School for Cookery, South Kensington, who kindly volunteered to assist at the tests, details of which are given in the report of the Testing Engineer. The stoves submitted to the jurors for examination were uniformly satisfactory, although exhibiting a wide range of consumption, some requiring for the same description of work fully three times as much gas as others. The general tendency, however, amongst manufacturers is evidently towards the study and application of economical principles; in which some have been already conspicuously successful, while still leaving room for further improvement. The fact that a 12-lb. joint can be cooked in London at a cost of very little more than a penny for gas, with a prospect that this may reduced, ought to prevail with many a householder to try gas cooking, if only as an auxiliary to his present appliances.

Without doubt there is a great future before gas as a heating agent, and too much publicity cannot be given to the various uses to which it can be applied. For so simple a purpose as ironing, the laundress may be materially assisted by such an arrangement as was exhibited, for keeping irons continually hot while in use by means of a gas jet. For the rapid heating of water for the supply of baths and other domestic purposes gas was shown to lend itself with great facility, the action of the heaters consisting of the application of the gas to a stream of water on its flow from the pipe or cistern to the point of use, the temperature being raised in proportion to the quantity of gas used and the volume of water delivered.

Heating-stoves were represented by almost every conceivable form, from the suspended fire basket to the elaborate and scientifically constructed ventilating stove. The latter class claim special attention, as being calculated in an eminent degree to promote sanitation. A ventilating stove when properly constructed and put in action may be made to secure a constant ingress of warmed fresh air, and thns any desired temperature may be maintained in a room without sensible variation for almost any length of time, and without the trouble of attendance and regulation. At the same time the prodncts of combustion are carefully got rid of—a point of great importance, and upon which it is impossible to lay too much stress; especially as it is a condition which may in all cases be satisfactorily fulfilled without much waste of heat. For cooking-stoves a cheap hood of wrought iron placed overhead, and communicating with a flue or with the outer air, effectually prevents annoyance from the escaping products of combustion, or the smell given off while cooking is going on.

The tests which were made with the various heating-stoves exhibited, show that any room of moderate dimensions may be effectually warmed with a consumption of gas not exceeding from 10 to 15 feet per hour.

Gas fires are deservedly becoming popular on account of their cleanliness and convenience, requiring no attendance when alight, and thus saving in many instances a very appreciable sum per annum in servants' wages. They are not, however, so economical in point of consumption as heating-stoves, their effect depending mainly upon the amount of radiant heat which they are capable of producing, so that probably not more than one-third of the total heat produced by the combustion of the gas is made available in this form; nevertheless improvements conducing to greater economy were observable in gas fires, a very fair effect being in some instances produced with a consumption of not more than 18 to 20 feet per hour. As a matter of course gas used in this way cannot be so economical as solid fuel, with which it compares favourably only when the heat evolved by it can be completely utilised; and the desire of the public for a cheerful, clean, and at the same time economical fire has been sought to be met by combining with gas some form of solid fuel. A noticeable feature of the Exhibition was the frequent adoption of the form of fire introduced by Dr. Siemens, consisting of a combination of gas and coke or gas and anthracite coal, evincing considerable attention to the principle on the part of the exhibitors. The jurors, however, were not convinced by any of the examples shown, that any distinct advantage is the result of such a combination beyond the fact that, by the occasional aid of a gas flame, the combustion of coke may be sustained more satisfactorily than when used alone and under less favourable conditions as regards draught. As a smokeless and comparatively inexpensive fire, they have regarded the combination as one deserving consideration. At the same time they would urge the convenience of gas when used as a simple fire-lighter, a very useful device for which was exhibited by Messrs. Strode & Co.

The application of gas to manufactures was mainly represented by a form of tinman's stove exhibited by the Lancashire Gas Meter Company, in which the principle of the blowpipe is introduced with considerable advantage, and by the exhibits of Messrs. Thompson Brothers of Leeds. This firm for the first time publicly exhibited their gas kiln for burning pottery and stained glass, and for annealing and bending glass. The jurors were led to the opinion, as the result of their examination, and inquiries respecting this kiln at the manufactories where it was in use, that it is a highly successful example of the application of gas in the ordinary way to an entirely new field, in which it contrasts most favourably with solid fuel. The furnace is capable of being raised to a temperature of upwards of 2,000° Fahrenheit; and it appears from the statements of the users—namely, Messrs. Powell & Co. of Whitefriars, and Messrs. Britten & Gilson of Union Street, Sonthwark—that whereas, with the old method of a muffle, heated by solid fuel, a single fire occnpied the whole day, the gas kiln can in the same period be fired as many as six times. There is thus a very important

advantage gained in the saving of time, since the different colours used in glass-staining have to be separately burnt in; but in addition to this the saving of labour is appreciable, while the cost for fuel remains the same, or, if any variation, less.

Messrs. Thompson Brothers also exhibited a small baker's oven, heated by gas upon similar principles, which gave every indication of proving a success. It is needless to observe that a great improvement is thus in prospect over the present wasteful, laborious, and even barbarous system of firing bakers' ovens, which produces vast quantities of smoke, and materially pollutes the atmosphere.

There was a considerable variety in the display of gas engines, giving satisfactory evidence of the activity of invention in this direction. It cannot be too generally known that the direct application of fuel in a gaseous form for conversion into motive power is far more economical than the use of the same fuel for the production of steam in a boiler; and the remark applies, only in a less degree, to a majority of cases in which ordinary illuminating gas is employed in connection with engines of moderate power; nor need it be regarded as a mere matter of speculation as to whether or not the gas engine will displace the steam engine, seeing that such displacement has already commenced, and that in every town of importance the number of such engines may be counted by hundreds, notwithstanding the comparatively short time that has elapsed since it was brought by the labours and inventive genius of Otto and of Crossley to its present state of comparative perfection. The jurors, not having had an opportunity of examining minutely and testing the various gas engines exhibited, are not in a position to make any award for them.

Improvements in the use of gas for illuminating purposes formed a conspicuous part of the Exhibition, notably the lamps of Messrs. Sugg & Co. at the entrance in the Exhibition Road and near the lecture-room, and those of Messrs. Siemens in the conservatory. Great advances have been made of late years in this direction, and burners are now made that give a largely increased amount of light for the same consumption of gas over those that were to be obtained a few years ago, although in too many instances the old burners and globes are still in use, and most of them are not giving the amount of light that is due to the gas consumed. In connection with burners, regulators of various forms and types were exhibited. These are very useful instruments, and their adoption is calculated to bring the use of gas into more general favour, as by them the supply to the burners is adjusted to the correct quantity and kept uniform.

As the supply of gas for illuminating purposes and its regulation cannot be considered as directly conducive to the abatement of smoke, the jurors did not consider themselves justified in making any awards to the Exhibitors of apparatus having this end in view, although they at the same time feel that much valuable and praiseworthy work was shown by many Exhibitors.

From the large amount of gas apparatus exhibited, and the attention that is now being given to its manufacture, it would appear that the use of coal gas as a fuel is likely to spread largely, and to become one of the readiest and most practicable means of abating the smoke nuisance in London and other large towns.

The jurors have divided the coal-gas exhibits into two grand divisions:

1st. Cooking-stoves.
2nd. Heating-stoves.

They have subdivided the cooking-stoves into :

(*a*) Stoves suitable for families of about twelve persons.
(*b*) Stoves suitable for large establishments.

And the heating-stoves into—

(*c*) Close stoves, from which the heat is conveyed into the apartment by

conduction from pipes or chambers, through which the heated products of combustion pass.

(*d*) Open stoves, or combination fires, in which gas is burned in combination with solid materials, and the heat radiated into the apartment.

(*e*) Gas baskets, or fires, from which the heat is conveyed by radiation.

For a general description of the exhibits, see the reports of Mr. D. K. Clark, Testing Engineer to the Committee.

In making the awards for the cooking-stoves, the jurors have considered chiefly the amount of gas required to do a certain amount of work, and the manner in which the work was done, at the same time bearing in mind the workmanship and construction of the stoves, their finish and probable durability, coupled with price, also the facilities for doing the work, and any special features with which each one was credited.

And, for the heating-stoves, the amount of gas and other fuel consumed in a given time, coupled with the temperature to which the air of the apartment was raised, the ventilation produced, and the means of removing the products of combustion, also the general appearance of the stoves, their workmanship, and adaptability for domestic use.

The following is the list of awards recommended in this section :—

LIST OF AWARDS.

Gas Oven.

To Thompson Brothers, Leeds, a Gold Medal for their Patent Kiln and Baker's Oven, being a distinctly new application of the use of Coal Gas, and one calculated to largely promote the abatement of smoke.

Gas Cooking-Stoves.

(*a*) *Stoves suitable for families of about twelve persons.*

To H. & C. Davis & Co., Camberwell, Silver Medal.
To Beverley & Wylde, Leeds, Silver Medal.
To J. Wright & Co., Birmingham, Silver Medal.
To J. C. Stark & Co., Torquay, Silver Medal, in recognition of the principle adopted by them of burning the gas outside the oven in which the cooking is carried on.
To Billing & Co., New Oxford Street, Bronze Medal.
To S. Leoni & Co., New North Road, London, Bronze Medal.
To Charles Wilson, Leeds, Bronze Medal.
To Waddell & Main, Glasgow, Bronze Medal.

(*b*) *Stoves suitable for large establishments.*

To J. Slater & Co., Holborn, Silver Medal, for Excellence of Material and Workmanship.

Gas Heating-Stoves.

(*c*) *Close stoves, from which the heat is conveyed into the apartment by conduction from pipes or chambers, through which the heated products of combustion pass.*

To J. C. Stark & Co., Torquay, for Cox's Ventilating Gas Stove, a Silver Medal.
To The Sanitary and Economic Supply Association, Gloucester, for Dr. Bond's Euthermic Ventilating Stove (Pattern A), a Silver Medal.

(*d*) *Open stoves, or combination fires, in which gas is burned in combination with solid materials, and the heat radiated into the apartment.*

To WADDELL & MAIN, Glasgow, for Dr. Siemens' Gas-and-Coke Fire, a Bronze Medal.

To G. WRIGHT & Co., Rotherham, for Dr. Siemens' Gas-and-Coke Fire, a Bronze Medal.

(*e*) *Gas baskets, or fires, from which the heat is conveyed by radiation.*

To S. LEONI & Co., New North Road, London, for Hanging Gas Fire, a Bronze Medal.

For a description of each article that was tested in this section, and particulars of the results of the tests, see Mr. Clark's Report, page 102.

IV. REPORT OF THE JURORS ON GAS-PRODUCERS.

Two systems of generating combustible gases from solid fuels were exhibited. The Wilson Gas-producer, exhibited by Bernard Dawson, is a vertical chamber, about 10 feet deep, kept nearly full of small bituminous coal. A mixture of air and steam, comprising 20 parts of air to 1 part of steam by weight, is delivered into the lower part of the chamber, the air being induced by two small jets of steam. The fuel is resolved into the combustible gases, carbonic oxide and hydrocarbons, in the manner of the ordinary gas furnace; and the cost of production of the heating gas is, it is said, less than a halfpenny per 1,000 cubic feet. This statement was not submitted to proof by any form of test; and it remains to observe that the gas-producer exhibited by the Dowson Economic Gas Company, for the production of cheap gas, was tested with good results. It was proved that the cheap gas could be produced at a cost, including general charges, of 4*d.* per 1,000 cubic feet, and that it was successfully and economically applicable, not only as a heating agent, but also a motive power.

The jurors recommend that the following award be made:—

To THE DOWSON ECONOMIC GAS COMPANY, Great Queen Street, Westminster, for their system of producing Cheap Gas; and the applicability of the gas as a generator of heat, and as a motive agent, a Gold Medal.

For a description of the Dowson Gas-producer, and particulars of the results of the tests, see Mr. Clark's Report, page 112.

V. REPORT OF THE JURORS ON APPARATUS FOR HEATING ROOMS AND BUILDINGS BY HOT AIR, HOT WATER, AND STEAM CIRCULATION.

THE jurors have confined their attention to the Hot-Water apparatus exhibited, which alone was subjected to tests sufficient to establish the relative efficiency of different apparatus. Three systems of warming by hot water were tested—distinctly different from each other, and affording instructive contrasts:—Franklin, Hocking & Co.'s system, consisting of two circuit-lines of hot-water pipes, placed near the walls; Deards' system, consisting of a coil of water-tubing which formed the fire-place, and was connected with a cistern, and in which water was rapidly heated and circulated; and Stainton's, in which, also, a coil of water-tubing formed the fire-place; and in which, with an extensive coil in the middle of the room, the heated water was circulated under very high pressure, and, of course, at a high temperature.

The drift of the evidence points to the greater efficiency of the smaller circulating piping; and the jury recommend that the following awards be made:—

LIST OF AWARDS.

To W. & S. DEARDS, Harlow, Essex, for their Coil Heating-Apparatus, a Bronze Medal.

To W. STAINTON, Liverpool Street, King's Cross, for his Frost-Proof Hot-Water Apparatus, a Bronze Medal.

For a description of the articles that were tested in this section, and particulars of the results of the trials, see Mr. Clark's Report, page 115.

VI. REPORTS OF THE JURORS ON STEAM BOILER APPLIANCES.

From the point of view of the Exhibition, this class of appliances are of special interest, as it was by their aid that the first efforts were made to abate the nuisance arising from smoke. James Watt appears to have suggested (1785) the use of smoke-consuming boiler furnaces, fed with cold air; but in 1801 Roberton adopted an arrangement devised by Watt, in which cold fuel was fed behind the incandescent mass on to a slightly inclined grate. On the other hand, Darcet in France, and Parkes in England, seem to have been the first to attempt the solution of the problem by an alternative scheme, which involved the admission through the *fire-bridge* of a stream of heated air, with a view to complete the combustion of the smoke and gaseous products; while a third scheme was patented in 1837 by Fairbairn, who provided two grates, and so arranged the stoking that when one furnace is in full combustion, the gaseous products from the other pass over a mass of incandescent fuel, the direction of the combustible gases and smoke being alternated from time to time.

Numerous plans for the prevention of smoke followed the efforts of James Watt, but in this country the question does not seem to have assumed public importance until 1829, when a Select Committee of the House of Commons specially considered the effect of factory furnaces in relation to public health; and in 1843 another Committee inquired into the 'means and expediency of preventing the nuisance of smoke.' Since that time the use of mechanical appliances for lessening the production of smoke has gradually increased.

Great progress has been made since the beginning of the century in the use of waste gases of blast and other furnaces for heating steam boilers, and knowing how much has been done in this direction, the jury cannot refrain from expressing their disappointment that no form of boiler furnace was submitted to them in which fuel is converted into gas before it is used for heating the boiler.

The jurors find that much misconception prevails as to the economy attending the combustion of smoke. It is urged, even by modern authorities, that the combustion of smoke is not economical, because the excess of air which it is necessary to introduce through the fire to effect the combustion of smoke has to be heated, and the heat so applied more than balances that produced by the combustion of the smoke. As regards actual sooty smoke, the solid carbon in which probably does not exceed 1 per cent. of the amount in the fuel burnt, this view may be correct, but the completion of the combustion of invisible carbon present in the gaseous products, as carbonic oxide or as hydrocarbons, is certainly remunerative, and the tests made by Mr. D. Kinnear Clark show that increased efficiency, measured by evaporative power of the fuel, was obtained by the use of many of the various appliances exhibited.

The jurors also find a widespread belief that a careful stoker can attain by skilful treatment of the boiler fire all the effects that a mechanical smoke-consuming appliance will yield, and the uniformity with which 'mechanical stokers' act has often been urged as a reason against their use. With reference to this point, the jurors consider that marked advance is shown by the care taken in devising appliances to meet the requirements of daily practice, and they are satisfied that mechanical appliances

may readily be adjusted so as to meet the changing needs and conditions of the furnace, and that they are, in the end, less costly than the skilled labour required to produce equal results by hand-firing.

MECHANICAL STOKERS.

Mechanical stokers are designed with the following objects: viz., the substitution of mechanical power for the manual labour of the stoker, the delivery of a small and continuous supply of fuel to the furnace in the place of the larger quantities cast in by hand from time to time as required, and the constant movement of the fire-bars by which the adhesion of masses of clinker to the bars is prevented, thus permitting at all times the free access of air beneath the fire to promote combustion.

The use of mechanical stokers is of the greatest importance in abating smoke. Not only is the saving of labour very considerable and the saving of fuel most marked, but in nearly all the forms shown in the Exhibition and tested while in operation, smoke was during their working either entirely avoided or much reduced in amount, but most of them require occasional assistance by hand, thus showing that they are still open to further improvement.

The mechanical stokers exhibited are divisible into two classes, viz.:

I. Those delivering the coal in the front of the fire, where it is gradually coked and pushed backwards over the fire-bars.

II. Those which operate by spreading or scattering the fuel over the whole surface of the grate.

In Class I. we have the following:—

Vicars' Patent Self-Stoking Smokeless Furnace.

In this the alternate fire-bars are lowered and drawn towards the front of the boiler, and then the whole of the bars travel forward together. The feed of fuel is effected by pushing the coal in from hoppers placed in front of the boiler, and down which it passes to the faces of the plungers or rams. The fire-bars have a stroke which can be adjusted from 0″ up to 4″. The motion is derived from an over-head shaft, provided with an eccentric at each end, working a ratchet wheel and pawl by which a horizontal shaft on the front of the stoker is made to revolve. The bars take their motion from the horizontal shaft by means of cams. The cams are so designed that one set of alternate bars is lowered, drawn towards the face of the furnace, and raised. The other set of bars then goes through the same movement, and the cycle is completed by both sets of bars being thrust back into the furnace together. The speed of the horizontal shaft and fire-bars can be adjusted from 30 to 120 revolutions per hour by varying the travel of the pawl on the ratchet wheel. When required, the furnace can be fired by hand through a door between the rams.

Sinclair's Mechanical Self-Acting Stoker.

In this the coal is fed into the furnace from a hopper, as in Vicars's, but the feed is varied by the adjustment of the stroke of the ram from 1½″ to 4″. The fire-bars are in five sections, each section consisting of three bars, the outer bars being flanged and the centre one being of the herring-bone section. The far end of the centre bar is bevelled,

and rises on a cross bearer as it is pushed back, so as to break up clinkers forming at the further end of the furnace. The motion of the fire-bars and the ram is taken from a five-throw crank shaft placed in front of the boiler, from each of which a short connecting rod gives motion to a section of three bars. The shaft is driven by a spur wheel and pinion and a belt pulley, and can be thrown out of gear by a clutch. The speed of the crank shaft is one revolution in 1¼ minute. There is no means of varying the ratio of the speeds of crank shaft and driving pulley. During the time this stoker was being tested the quantity of water evaporated per pound of coal was much lower than in some other forms exhibited, but on the other hand, the boiler being only temporarily erected was not set in brick-work or coated, and the coal employed was of a very inferior description. The excellence of this stoker was shown by the complete absence of smoke, and by the efficient manner in which it dealt with the heavy masses of clinker formed.

KNAP'S MECHANICAL STOKER.—*Exhibited by the Patent Steam Boiler Company.*

In this mechanical stoker the hopper from which the fuel is fed is provided with a slide, by which the supply to the crushing and feeding roller may be varied or entirely cut off. After passing the roller the coal falls down an inclined plane to the front of the pusher, which delivers it on to the dead plate and thence to the fire-bars, five of which are movable and six fixed. The movable bars are hooked at the front end and rest on a cross bar, to which a reciprocating motion is given by a pair of side levers working on a pivot, and which also give motion to the pushers. The entire mechanism is simple and well arranged, and is not liable to get out of order, but when tested it did not entirely prevent smoke.

MCDOUGALL'S MECHANICAL STOKER.—*Exhibited by the Chadderton Ironworks Company, Limited.*

This is somewhat similar in arrangement to Sinclair's. The whole of the bars are movable, and rest at their front end on a horizontal shaft of Bessemer steel. The shaft consists of a succession of cranks or eccentrics of ¾-inch throw, turned on three centres pitched at angles of 120 degrees apart. The far ends of the fire-bars rest on a bevelled cast-iron bridge, causing each bar to rise or fall as it is pushed forward or withdrawn. Each bar rests at its front end on its own eccentric or crank, thus its motion is one third of a revolution before or after that of each of its contiguous bars. The motion of the crank shaft is derived from pulleys of three speeds. The ram or pusher is of a less depth at the centre than at the sides, by which means the supply of fuel is kept lower at the centre. The coking plate upon which the fuel is first passed projects a short distance into the furnace, to facilitate coking, and is provided with apertures for the admission of air, thus the fuel is readily ignited before reaching the bars.

In Class II. we have :—

JAMES PROCTOR'S MECHANICAL STOKER AND MOVABLE FIRE-BARS.

In this a single hopper is placed between the two flues of the boiler. A ram at the bottom of the hopper pushes the fuel alternately to the right and left along two horizontal passages leading to a shovel box at each end, facing the flues. From each box a shovel, actuated by the release of a spiral spring, projects the coal into the furnace. The shovels are withdrawn to a different extent in each of three successive strokes by three cams giving a different degree of extension to the springs, thus imparting a different velocity of projection to the coal and causing it to fall on a portion of the furnace varied for each of three successive strokes. The springs can be adjusted to give the impulse required, and the impact of their recoil is softened by buffers. A flap door is provided for hand-firing when required. The fire-bars are rocked by a hand

lever in front of the furnace. When tested this stoker showed a light but continuous smoke, which was less than half that produced during hand-firing.

Holroyd-Smith's (Knowles and Halstead) and J. Newton and Son's mechanical stokers, are described in Mr. Clark's Report, pages 130, 131.

FIRE-BRIDGES, FIRE-BARS, FURNACE-DOORS, STEP AND INCLINED GRATES, &c.

The system of admitting air through a perforated fire-bridge, at a sufficiently-elevated temperature to effect the more or less complete combustion of the fuel, is so well known that it is not necessary to dwell on the principle. It may be added, however, that the Committee are of opinion that any system by which air is introduced with a view to *complete* the combustion either of gaseous or of solid fuel, that has been imperfectly burnt on the grate of the furnace, is objectionable, and is not likely to lead to the most economical results; and, further, in cases in which the amount of air introduced cannot be controlled either automatically or by hand, waste may arise in two ways: either sufficient air may not be admitted, in which case fuel will be wasted; or too much air may pass through the furnace, and thus lead to waste of heat.

Cast-iron Fire-bridge.—*Exhibited by Chubb & Co.*

A hollow cast-iron bridge is applied at the back of the fire-grate of internally-fitted boilers. Its end elevation is semicircular, and it is faced on the side next the fire with a thick tile of fire-clay. Two semicircular cast-iron wedges are so placed between the external walls of the bridge as to leave three transverse slots, each about an inch wide, through which streams of heated air are supplied to the flame as it passes over the bridge, the semicircular form of which promotes the admixture of the air with the combustible gases and smoke. There is also a fourth slit, a lateral one, opening through the wall of the bridge nearest the fire. Air is admitted from the ash-pit to the bridge, the supply being regulated by two valves, one of which gives access to the lateral slit. The tests to which this appliance was submitted showed that smoke of a low degree of density was only emitted for a few minutes, and that during 98·4 per cent. of the time no smoke could be detected.

Tubular Fire-bridge.—*Exhibited by Ireland & Lownds.*

It consists of a number of cast-iron tubes bent thus ┐, the horizontal limbs of which are laid on the masonry of the fire-bridge of the furnace, while the other hangs down on the side next the fuel, and reaches below the fire-bars to the ash-pit. Air enters from the ash-pit, and is delivered at the upper end of each pipe through a horizontal grating. The air, after being heated by transmission through the pipes, thus meets the combustible gases from the fuel. The appliance proved efficient in consuming the smoke of a very bituminous coal, the pressure of steam being materially increased by its use while the amount of fuel consumed was diminished.

Vertical Grates in a Boiler Furnace.—*Exhibited by the Wavish Patent Fuel Economiser Company.*

A tube runs nearly along the axis of the fire-place of a Cornish boiler, and water circulates through this tube. On each side of the tube, but at a lower level, a nearly solid horizontal plate is arranged. These level dead plates extend the whole length of the furnace, and sloping grates rising from them serve to support the water tube. In

charging the furnace, these sloping grates are almost entirely covered with fuel, which reaches half up the tube. Air enters through the sloping grates, and the result is complete prevention of smoke when hard steam coal is used.

AN 'UNDER-FED' STAGE GRATE.—*Exhibited by James Farrar & Co.*

This is a modification of the well-known 'step' grate devised for burning bituminous coal in a fine state of division. The steps on which the fuel rests are arranged in four stages, each of which is 9 inches above the other. The first, second, and third from the top are formed of plates 3½ feet wide, terminating, on the fuel side, in grates partly horizontal, and partly inclined thus, . The fourth and lowest stage is a horizontal grate, and on it clinkers and ash are collected. The important feature of the appliance consists in the facility with which the incandescent fuel covering the steps may be 'under-fed' by placing fine 'slack' coal on each of the stages, and by pushing the fuel gently inwards. As is usual in step-grates, the fuel falls gradually from the top to the bottom of the series of steps, so that an inclined bed of fuel is readily formed. The tests showed that no smoke whatever escaped from the chimney.

ORVIS'S STEAM INJECTOR.—*Exhibited by the Great Britain Smoke Consuming Company.*

It has long been recognised that the efficiency of the system of injecting air by means of a steam jet, with a view to completing the combustion of fuel, depends on the mechanical intermingling of the air and gaseous products of combustion which is thus brought about. The tests showed that, in burning Welsh coal, the evaporative power of the fuel was increased by the use of the appliance, whilst the smoke evolved was of a low degree of density.

BLOCKSAGE'S SMOKE-CONSUMER AND FUEL-ECONOMISER.—*Exhibited by John Collinge.*

It consists of an inclined grate, external to the boiler, and set in a fire-place of fire-resisting clay slabs. These become strongly heated, and, by heating the air, completely effect the combustion of smoke.

BALANCED DOOR.—*Exhibited by W. A. Martin & Co.*

Of the numerous forms of furnace-doors exhibited, the jurors consider that this door possesses the greatest merit. The supply of air can be readily adjusted by its aid, and the test showed that the appliance was efficient in preventing smoke.

LIVET'S METHOD OF SETTING BOILERS.—*Exhibited by the Livet Boiler and Furnace Company.*

The system consists in providing the boilers with flues which gradually enlarge as they advance from the fire-place. The products of combustion after leaving the fire tubes of Cornish or Lancashire boilers are conducted back to the front by a lateral flue of larger sectional area than the internal tube or tubes collectively. The gases then pass back again by a second lateral flue of still larger sectional area than the first. Two capacious chambers are placed, one at each end of the boiler, for the collection of dust and carbon, and the sectional area of the chimney enlarges towards the top. It is asserted that, by Mr. Livet's arrangement of enlarging flues, the draught is improved, and, in consequence of the retarded velocity of the current, a greater proportion of heat is absorbed by the boiler than would be the case in a system of flues of uniform section. Satisfactory evidence was afforded as to the increased evaporative power of the fuel attending the adoption of the system, which also proved useful in preventing the evolution of smoke. The fire-bars are wedge-shaped in section, and being of unusual depth, have been divided into an upper and a lower portion in order to protect them from fracture by expansion.

Atmospheric Chimney.—*Exhibited by E. G. Wéry.*

M. Wéry's system of promoting draught and combustion, by spirally-directed currents of cold air in the chimney, was original; and it proved very effective.

The following is the list of awards recommended in this section:—

LIST OF AWARDS.

Mechanical Stokers.

To George Sinclair, Albion Works, Leith, a Silver Medal.

To T. & T. Vicars, 29 Seel Street, Liverpool, a Silver Medal.

To The Patent Steam Boiler Co. (Knap's), 28 Heneage Street, Birmingham, a Bronze Medal.

To The Chadderton Ironworks Co., Limited, 10 Mark Lane, London, E.C. (M'Dougall's), a Bronze Medal.

To James Proctor, 5 Albion Terrace, Burnley Lane, a Bronze Medal.

Fire-Bridges.

To Chubb & Co., of 28 New Bridge Street, London, E.C., for their Cast-iron Semicircular Fire-Bridge, Bronze Medal.

To Ireland & Lownds, of 46 West Street, Leek, Staffordshire, for their Cast-iron Tubular Fire-Bridge, Bronze Medal.

Fire-Bars and Grates.

To The Wavish Patent Fuel Economiser Company, 110 Cannon Street, London, E.C., for an Application of Vertical Grates in Steam Boiler Furnaces, Silver Medal.

To James Farrar & Co., Old Foundry, Barnsley, for Barber's Under-Feeding Stage Grate, Bronze Medal.

To John Collinge, Wallshaw House, Oldham, for Blocksage's External Inclined Grate, Bronze Medal.

Furnace-Doors and Fittings.

To W. A. Martin & Co., Pocock Street, Blackfriars Road, London, E.C., for a Balanced Fire-Door, Bronze Medal.

To The Great Britain Smoke Consuming Company, St. Stephen's Chambers, Telegraph Street, London, E.C., for Orvis's Steam Injector for Consuming Smoke, Bronze Medal.

Boiler Setting.

To Livet's Patent Improved Boilers and Furnace Company, Short Street, Finsbury Pavement, London, for Mr. Livet's Method of Setting Boilers, and for Fire-Bars, Silver Medal.

Chimney.

To E. G. Wéry, Paris, for his Atmospheric Chimney, Bronze Medal.

For a description of each article that was tested in this section, and particulars of results of tests, see Mr. Clark's Report, page 118.

VII. REPORT OF THE JURORS ON KILNS AND OVENS.

1. MINTONS' Smokeless Pottery Oven or Kiln was represented by a large drawing, showing in full detail the design and construction of the oven as in operation at the works of the exhibitors, at Stoke-on-Trent.

The patents of General H. Y. D. Scott, granted in 1868 and 1869, were used by Messrs. Mintons, and subsequently improved by them. In the earlier ovens, the fuel was burned in feeders or mouths, disposed partly on the outer circumference of the oven, and partly under the walls. On this system, much of the heat radiated from the fuel, and contained in the gaseous products of combustion, was lost in heating the brickwork. In Messrs. Mintons' patent of 1873, the old feeders are dispensed with, and the combustion of the coal is entirely effected inside, or in the hold of the oven, so that the heat is directed on the saggers containing the ware, and economy of fuel is effected. Besides, by the addition of a second chamber on the top of the oven, means are provided for utilising the heat that passes from the oven, for hardening printed ware, or for firing articles of pottery for which a low heat is necessary.

The feeders, of which there are a considerable number ranged round the oven, are constructed on the principle of the gas furnace, in which the coals are piled on a grate in a bed of considerable depth, from which the combustible gases, carbonic oxide and hydrogen, are discharged. These are met by regulated supplies of air introduced in the upper part of the furnace, for the purpose of effecting their complete combustion, with an extended circulation of the flame. The flues leading to the outer chimney are free from inflammable gases, and they hold a sufficient proportion of free air to constitute a highly oxidising mixture, securing richness of colour and glossiness in the glazed ware. Taking into account that Mintons' oven holds more goods than old ovens of equal diameter, it is reckoned that the saving of fuel effected by Mintons' oven is not less than 40 per cent.

A deputation of the Committee—consisting of the following members: Dr. Siemens, F.R.S., LL.D., Col. Festing, R.E. (Science and Art Department), Wm. R. E. Coles, C.E., accompanied by their engineer, D. Kinnear Clark—visited Mintons' works on December 28, 1881; and they inspected the under-mentioned ovens:—

One earthenware biscuit oven,
Two earthenware glost ovens,
One china biscuit oven.

They also inspected a large tile oven at the Campbell Tile Company's Encaustic and Floor Tile Works.

The ovens were firing in various stages, without the slightest trace of smoke from the summit.

2. JAMES DUNNACHIE'S Continuous Regenerative Kiln, for burning bricks, pottery, &c., patented in 1881, was inspected in operation at the Glenboig Star Fireclay Works on June 6, 1882. An actual test for consumption of fuel was not made; but, from the results of examination and inquiry, it would appear that the saving in fuel may be estimated at fully 50 per cent.; and that the saving in time of 'full firing' is equally important. The kiln is constructed to burn gaseous fuel, obtained from two producers,

each of which is capable of decomposing 4 cwt. of slack per hour. Ten ovens are placed in circuit, and are so connected that the hot gaseous products of combustion from an oven 'on full fire' are passed into and through the next oven in advance, where the fresh bricks are dried by the heat, and prepared for full fire. From the preceding oven, a supply of heated air for supporting combustion at a high temperature in the oven on full fire, is obtained by passing the air for combustion through the piles of hot bricks which are left to be cooled before being withdrawn. By this arrangement, a twofold source of economy is opened—the heating of the air for combustion by the residual heat of the oven full of burnt bricks, and the drying of the fresh bricks by the hot products of combustion, which pass from the oven on full fire, on their way to the chimney.

The Regenerative Kiln is practically smokeless. It is adapted for burning the most refractory bricks and blocks; but it can be adjusted to burn ordinary building bricks. The working cost for personal attendance upon the kiln appears to be about the same as for that of the ordinary system; but the saving of labour connected with the supply of fuel to the producers, and from the better internal arrangement of the works, is considerable.

3. THOMPSON BROTHERS' Smokeless Gas Oven, for burning stained and painted glass, enamel colours, and pottery; for coffee-roasting, baking, and annealing. The fuel is gas, applied atmospherically. For baking bread, the gas is applied, not within the oven, but externally. The gas is made to pass round the oven, commencing at the top, passing down the sides, and under the floor, to a flue at the back. The construction of the oven is simple, as there are no furnace-doors, fittings, bars, nor ashpit. According to the results of a test made February 6, 1882, the oven, being cold, was lighted; and in the course of an hour and a half the temperature was raised to 350° F., for doing which 270 cubic feet of gas were consumed. The gas was then shut off, and the dampers closed; and two hours later the temperature had risen to 600°, in consequence simply of the transmission of heat from the flues. Three hours after turning off the gas the temperature was 450°; eight hours after, it was 320°; and 22 hours after, it was 140°. The gas was again lighted, and in one hour, consuming 180 cubic feet of gas, 300° of temperature was attained. The gas was then turned off. Bread was baked in 55 minutes, and, when it was drawn, 350° of temperature remained. Six hours after the gas was turned off there were 250° of temperature. Thompsons' gas oven has already been noticed in Report III. of the Jurors. It is here noticed specifically with respect to its employment for baking. Its heat-retentive power, in maintaining high temperatures for a great length of time after the supply of gas has been turned off, is a feature sufficiently remarkable to deserve further analysis.

For burning glass and pottery, the gas is laid on inside the oven, and flames up from each side, across the arch, over the entire length and breadth of the kiln. At the works of Messrs. Britten and Gilson, Southwark, gas kilns have been erected, one of which, holding 12 square feet of glass (4 feet by 3 feet), is fired at a cost of 1*s.* 2½*d.*, for fuel and attendance; whilst a muffle-kiln previously nsed, cost, for coke and labour, 4*s.* 3*d.* The gas kiln can be fired six times in twelve hours; the muffle-kiln only once in twenty-four hours. (Plate 65.)

In concluding this notice of kilns and ovens, it may be observed that they comprise respectively—perfection of combustion on a large and practical scale; utilisation to a great extent of heat otherwise wasted, and great increase of efficiency for operations involving extremely high temperature; and an admirable application of the heating power of gas for purposes hitherto carried out in the clumsiest manner by the combustion of coal.

It appears to the jurors that it would materially promote the development and extension of these inventions, affecting important industries, if they were submitted to full and precise tests, for future publication.

VIII. REPORT OF THE JURORS ON ACCESSORY EXHIBITS.

THERE was a variety of articles exhibited which, though useful and important, were not recognised as directly conducive to the abatement of smoke, and as such, eligible for receiving awards. Self-acting Gas-valves or Governors belonged to this class; and of these there were a few of established merit. There was the Regenerator Gas Lamp of the Siemens Patent Gas Light Company—a lamp of exceptional brilliancy and power. (Plate 66.) There were several gas-burners and minor applications of gas for smoothing-irons and soldering-irons. Chimney ventilators and smoke curers were exhibited in considerable variety, and of these T. B. Papier's Chimney Ventilator may specially be mentioned. The 'Æolus' Spray Ventilator, exhibited by E. Moritz, was an elegant contrivance for supplying moist, cool air to a room in warm weather.

The Silicate Cotton, or Slag Wool, exhibited by C. Baatsch proved to be of a high degree of efficiency in resisting high temperatures, and in its non-conducting qualities. It was applied to several boilers in the Exhibition, and to the steam cylinders of the engines employed to generate the power for Dr. C. Wm. Siemens' Electric Furnace. It was also employed as the non-conducting medium encasing the crucible of this furnace. A. Haacke & Co. also exhibited a non-conducting composition, W. Berkefeld's Fossil Meal, which could be laid on the surface of boilers, &c., like plaster, only requiring to be kneaded with hot water before being used. The Fossil Meal consists of the purest silicious earth (Diatomacea), mixed with hair and some gluten, forming a plastic material. It was applied to the Vertical Steam Boiler exhibited by George Green.

Dr. C. William Siemens' Electric Furnace, exhibited by Siemens Brothers & Co., was frequently exhibited in operation. It consists of an ordinary crucible of plumbago or other highly refractory material placed in a metallic jacket or outer casing, the intervening space being filled up with a bad conductor of heat,—in this instance, slagwool. A hole is pierced through the bottom of the crucible for the admission of a rod of iron, platinum, or dense carbon, such as is used in electric illumination. The cover of the crucible is pierced for the reception of the negative electrode—by preference a cylinder of compressed carbon. It is found in practice, that a current of 100 webers, having a resistance of 50 ohms, and representing 6 horse-power of energy, melts $1\frac{1}{2}$ kilogrammes of steel in a quarter of an hour, in a hot crucible. This is equivalent to 6 kilogrammes melted per hour, with 8 kilogrammes of coal used under boilers, or 1·3 kilogrammes of coal per kilogramme of steel; or 1·3 pounds of steel per pound of coal.

The Compagnie Générale des Conduites d'Eau exhibited a Coke Breaker: a machine for breaking up coke and assorting the broken coke into various sizes. The coke to be broken is delivered into a hopper, from which it descends and is broken between two series of toothed discs, revolving on two parallel shafts, thence falling into a revolving cylinder of plate-iron, perforated with holes of successively enlarged diameter. The cylinder is slightly inclined; and the coke, travelling slowly downwards, is sifted into five lots of coke of different sizes. The production is four tons per hour; the power required, one and a-half horse-power.

IX. SPECIAL PRIZES.

Dr. Siemens' Prize.—*One Hundred Guineas.*

For the best method or arrangement for utilising fuel for domestic or industrial purposes with the least production of smoke. Divided, and awarded—

To The Dowson Economic Gas Company, Great Queen Street, Westminster, for Gas Producer and several applications of the Gas, Fifty Guineas.

To The Falkirk Iron Company, Upper Thames Street, for Gas-and-Coke-Burning Kitchener, Fifty Guineas.

Ladies' Prize.—*Fifty Guineas.*

For Smoke-Preventing Domestic Open Grate.

Competition kept open.

Ladies' Prize.—*Fifty Guineas.*

For the best Smoke-Preventing Coal-Burning Kitchener. Divided, and awarded—

To T. J. Constantine, Fleet Street, for 'Treasure' Stove, Twenty-five Guineas.

To The Eagle Range Company, Fleet Street, Twenty-five Guineas.

Society of Arts.—*Silver Medal.*

For the best Smoke-Preventing Coal-Burning Furnace. Awarded—

To C. B. Gregory (Beverley, New Jersey), for Smoke-Burning Furnace adapted to Domestic and Industrial Purposes, and tested for Stove, Kitchener, and Steam Boiler.

Manchester Association for Controlling the Escape of Noxious Vapours.—*Fifty Pounds.*

For Appliance for Preventing Smoke in Steam-Boiler Furnaces.

Competition kept open.

CHEMICAL REPORT

ON THE GASES WITHDRAWN FROM FLUES TO WHICH THE GRATES AND STOVES WERE ATTACHED.

By Professor W. Chandler Roberts, F.R.S.

ALTHOUGH elaborate experiments have been made from time to time with a view to ascertain the nature of the gases generated in furnaces, but little attention has been devoted to the composition of the gases given off from stoves and grates.

The first researches on chimney gases are due to Péclet[1] who published some analyses in 1828, but his results and those of different experimenters who followed him were open to the objection that the samples taken for analysis were only small fractions of the total gases in the flues, and, as they were not taken with sufficient frequency, they could not represent the mean composition. This grave defect was however remedied by M. Scheurer-Kestner in an elaborate research on the composition of the flue gases of boiler furnaces, which will always form the basis of future experiments in this direction.

A series of experiments conducted by this distinguished chemist in conjunction with M. Meunier in 1868,[2] on the combustion of fuel in boiler furnaces showed the difficulty of burning fuel completely on the grate of a furnace, and the analysis of the gases, made by them, led to the conclusion:—that the products of combustion always contain unburnt constituents even in the case of a thin layer of fuel and an excess of air of more than 50 per cent., that is to say, with volumes of 15 cubic metres of air for every kilogramme of coal burnt instead of 8 to 10 cubic metres. They also showed that the mean proportion of unburnt hydrogen reached 20 per cent. of the total amount present, which pointed to the fact that hydrogen is more difficult to burn, even under favourable conditions, than carbonic oxide, and that with a thin layer of incandescent fuel the unburnt carbon in the gas exists more often in the form of a hydrocarbon than of carbonic oxide.

In any such experiments it is impossible to collect the gases over water, as their relative proportions would be changed by the unequal absorption of the constituents, but by an ingenious device M. Scheurer-Kestner was enabled to aspirate continuously by water and to draw off, from time to time, subsidiary but representative samples in a small receiver containing about 3 litres of mercury. Such a mercury receiver is shown in the diagram, p. 36, and its insertion after the first chloride of calcium tube rendered it possible to withdraw a small measured volume of dry flue gas at fixed periods. I may incidentally mention that comparatively few of such subsidiary samples were withdrawn, but the appliance will, it is hoped, play an important part in the continuation of the work described in this report.

It must be borne in mind that the chemical question to determine in the case of the

[1] *Traité de la chaleur*, t. i. p. 299, (1828).

[2] *Mémoires extraits du Bulletin de la Société Industrielle de Mulhouse.* Lacroix, Paris, 1875. See also Scheurer-Kestner, *Recherches sur les produits gazeux de la combustion de la houille. Ann. de Chim. et de Phys.* t. xx. p. 66. 1870.

stoves and grates exhibited at an exhibition opened with a view to 'abate the nuisance arising from smoke' is to ascertain, 1st, to what extent the various appliances exhibited are smokeless, and 2nd, how far the absence of smoke really implies perfect combustion. The important point is therefore to determine how much carbonic anhydride (CO_2) is produced in each case, or, in other words, how much carbon is completely burnt, how much escapes as hydrocarbons or as carbonic oxide, and how much appears in the form of 'soot.' The soot is unimportant when compared with the other products of imperfect combustion, as the amount of fuel lost as soot is known to be small, and it is easy to ascertain by inspection whether much or little smoke is emitted from any particular appliance.

In the following experiments, the importance of securing a representative sample of gas was never lost sight of, but it must be remembered that a high degree of accuracy is not possible in the case of open grates, as the conditions vary from time to time with the amount of air entering above the fuel and diluting the flue gases.

After much consideration I determined to adopt continuous aspiration through a series of weighed absorbents, and, encouraged by the approval of Dr. Frankland, I submitted the following plan to the Committee. I believe the method I am about to describe differs from any hitherto adopted by the fact that evidence as to composition was elicited from the entire sample of gas withdrawn from the flues of grates and stoves during a considerable period of time.

A slow stream was drawn during several hours through a copper tube extending across the entire diameter of the flue, this tube being provided with a fine longitudinal slit which rendered it possible to draw the gases uniformly from the entire diameter of the section of the ascending current. In order to keep the slit free from soot a fine copper slip was caused to slide along it by means of a rod which could readily be worked externally to the flue. I should add that this form of tube for withdrawing the gases was suggested by M. Scheurer-Kestner in his classical series of experiments to which I have already alluded.

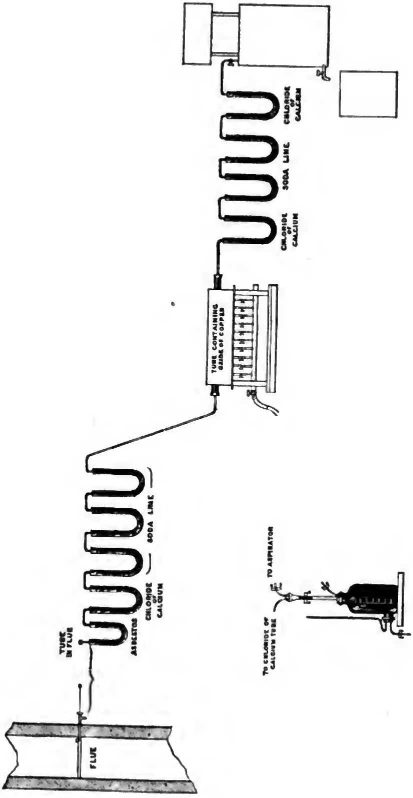
The position in the flue from which the gases are withdrawn is by no means a matter of indifference, at least in the case of very hot stoves burning anthracite. With a view to collect soot, it should of course be as near to the incandescent fuel as possible, but M. Cailletet showed [1] that the gaseous products from furnaces must not be collected immediately after being liberated from the fuel, for a current of gases from a mass of incandescent fuel may contain notably more carbonic oxide than the same gases do when cold; that is, by slow cooling combination of carbonic oxide and oxygen takes place. He gives the following analyses in proof of this; both samples were withdrawn from the same point, and their temperature was above 500° C. Sample I. was, however, rapidly chilled by withdrawal through a cooled tube, while II. passed through a hot metallic tube which facilitated partial recombination of the gases.

	I.	II.
Oxygen	7·65	1·21
Carbonic oxide	3·21	1·42
Carbonic anhydride	7·42	15·02
Nitrogen	81·72	82·35
	100·00	100·00

The point from which the gases were withdrawn in the flues at South Kensington was in each case 10 ft. from the ground, and I believe the gases which reached this point passed into the atmosphere without change. The thermometer and anemometer were also inserted close to the tube through which the gases were withdrawn.

After many preliminary experiments conducted in the Laboratory of the Mint, the following series of tubes was adopted, the general arrangement being shown in the accompanying drawing.

[1] *Bull. Soc. Chim.* Paris, t. vi. (1866) p. 104.



APPARATUS EMPLOYED FOR CHEMICAL TESTS.

The effluent gases passed first through a tube loosely filled with asbestos to retain the solid particles of carbon or soot. They then passed through a U-tube filled with chloride of calcium to absorb water, and thence through three U-tubes filled with soda-lime to absorb carbonic anhydride, a plug of chloride of calcium being placed at the further end to prevent any loss of moisture.

The above tubes were placed on the external wall of the chimney close to the point where the copper tube issued from the flue. The gases were then led through a glass tube to one of porcelain filled with cupric oxide heated to redness by means of a small furnace.

The complete combustion of the remaining gases was thus effected, the carbonic oxide being burnt to carbonic anhydride, and the hydrocarbons and free hydrogen to aqueous vapour and carbonic anhydride. The water was retained in a U-tube filled with chloride of calcium, and the carbonic anhydride in two other soda-lime tubes—the residual gases, oxygen and nitrogen, then passed to the water aspirator, a chloride of calcium tube being interposed to prevent any moisture from the aspirator penetrating to the system of tubes.

After the residual oxygen and nitrogen had had a sufficient time to mix by diffusion in the aspirator, samples were in some cases sealed up in glass tubes, with a view to future examination.

The above method would be comparatively simple if a pure form of carbon were the only fuel used, as the question would then mainly be to determine the relation between the carbonic oxide and carbonic anhydride produced by combustion; when, however, coal containing any bituminous matter is employed the asbestos tube will retain, in addition to the free sooty carbon, liquid and solid hydrocarbons. The asbestos tube also retains moisture either originally present in the fuel or the air, or in the mortar used in fixing the grate, in addition to the aqueous vapour which is produced by combustion of hydrocarbons. At the end of each operation it was necessary, therefore, to heat the asbestos tube gradually to about 200° C. This was at first done by means of a bath, but subsequently by the aid of a gentle flame, the aspiration being continued; so that the water and volatile solid hydrocarbons (if any were present) were thus driven forward and caught in the first chloride of calcium tube, while the gaseous hydrocarbons were expelled and burnt to carbonic anhydride and aqueous vapour by the glowing cupric oxide.

A tube containing asbestos might have been placed—as in M. Scheurer-Kestner's experiments—inside the flue, where the heat would have been in most cases sufficient to drive forward water and hydrocarbons; but it appeared to be better to place it outside, as the heat of the effluent gases in the chimney would certainly vary greatly with the different stoves or grates, and serious complications in the results might thus have been introduced.

No attempt was made to effect the condensation of the aqueous vapour by a Liebig's condenser, or other method of cooling, for, if the gas were cooled before passing to the asbestos, carbon would certainly be deposited with the condensed water and hydrocarbons, and, if the condenser had been placed after the asbestos tube, water and hydrocarbons would still be retained in the latter.

At the outset three methods of taking the samples presented themselves:—

(1) To draw through a certain fixed volume into the aspirator.

(2) To continue the aspiration for a definite period without regard to the volume of gas collected, or

(3) To combine these two methods, adjusting the rate of flow so that the volume collected in a given period of time is approximately constant.

Now it will be evident that in the open fire-place much of the air in the flue does not come in contact with the fuel at all, and that the dilution of the products of combustion by air varies with the rapidity of the draught. The displacement of a fixed volume of water in the aspirator would not then represent or indeed bear any relation to the volume

of gases absorbed by the reagents in the U-tubes, as the composition and temperature (and therefore density) of the gaseous column in the flue is continually varying.

If, on the other hand, the time be maintained constant, and a sufficient period be allowed to ensure a fair sample of the gas being taken, then the absolute volume drawn through will not be of importance, as the point to determine is the relative proportion of the products of complete and incomplete combustion as indicated by the increase of weight of the respective absorbents. If, however, the volumes drawn through are very variable, errors of weighing would introduce irregular variations of the results. The third method was therefore adopted.

The aspiration was in each case continued for three hours from the first lighting of the fire. The average volume of the gas drawn through the tubes ($\frac{1}{2}$ cubic foot or 14 litres) was rather more than $\frac{1}{100000}$ of that passing up the flue, this being a larger proportion than that employed by Scheurer-Kestner, who took about $\frac{1}{300000}$ of the gaseous products. In some cases the volume of the carbonic anhydride, absorbed in the tubes and weighed, was about half a litre, the other gases being in proportion.

In stating the results, the amount of carbon completely burnt to carbonic anhydride is taken as the unit of comparison (1,000); the carbon as carbonic oxide, and the carbon in the hydrocarbons are then expressed as thousandths (columns 6 and 7), and they represent the proportion of fuel more or less wasted as compared with that completely burnt.

The following are the analyses of the bituminous coal and the anthracite employed:—

	Bituminous, Wallsend	Anthracite	
	I.	I.	II.
Carbon	83·43	92·558	92·30
Hydrogen	5·12	2·107	—
Oxygen and Nitrogen	8·37	4·078	—
Sulphur	1·15	0·122	—
Ash	1·93	0·428	0·20
Moisture	—	0·107	—
	W. F. Ward	Dr. Cameron	Dr. E. J. Ball
	100·00	100·000	—
Coke	67·1 per cent.	—	91 per cent.

One objection to the method is that it does not distinguish between the half-burnt carbon existing in the flue gas as carbonic oxide, and the carbon present as hydrocarbons; for the combustion of these products is completed by the red-hot oxide of copper, and the carbonic anhydride contributed by each is ultimately weighed in the same soda-lime tube.

An attempt was made in some preliminary experiments to employ cuprous chloride with a view to absorb carbonic oxide, but the use of a moist reagent introduces many difficulties, and, as the results were unsatisfactory, it was abandoned.

The increase in weight of the first set of chloride of calcium tubes has been ignored, for, as they retain any moisture present in the fuel or in the air passing up the flue, they do not afford a trustworthy indication of the weight of water produced by the combustion of hydrocarbons or hydrogen in the fuel.

It should be further pointed out that the figures given in column 8 do not solely represent soot, or even the more solid particles of coal, as the asbestos tube will also retain fine particles of ash drawn up by the draught as well as fine dust from the mortar used in setting the stove. I regret that the asbestos plug, blackened by the adhering soot, was not in all cases separately burnt in oxygen with a view to determine the exact proportion of carbon it held, but I believe from the results of special experi-

ments that at least 84 per cent. of the increase in weight of the asbestos tube represents soot.

It must be remembered, however, that all solid particles of which the remainder consists would escape into the atmosphere and would constitute 'smoke.'

The results of the experiments are shown in the tables, and the following considerations appear to flow from them. The 85 cases given in the tables show that the relation by weight between the carbon completely burnt to carbonic anhydride and that present in the form of hydrocarbons or carbonic oxide varies between the limits of 1000: 4 and 1000: 375. There were however only nine cases in which a ratio of 1000 : 200 is exceeded, and but three in which the ratio is less than 1000: 10.

In 17 cases given by M. Scheurer-Kestner in his experiments on the nature of the gases of boiler furnaces, this relation varied from 1000: 10 to 1000:211, the result being mainly dependent on the amount of air introduced to effect the combustion.

With reference to the hydrogen it is to be observed that in the 17 experiments with boiler furnaces given by M. Scheurer-Kestner, the proportion of carbon completely burnt to carbonic anhydride to the hydrogen present either in the free state or as hydrocarbons varies from 1000: 3 to 1000: 16.

In the experiments at the exhibition the ratios obtained vary from 1000: 8 to 1000: 259, ratios which are much higher than the above, although they correspond with certain analyses made by M. Foucou [1] on the gases escaping from the furnaces of locomotives. It would seem, therefore, that an open fire-place need not compare unfavourably (from the point of view of effecting the complete combustion of carbon) with the boiler-furnace in which there is a larger mass of incandescent fuel; but it must be remembered that the appliances exhibited were in most cases specially designed for effecting complete combustion, and further, that the stoking was in all cases effected with great care, so as to ensure as favourable results as possible.

On the other hand, although in the case of the boiler furnaces tested by M. Scheurer-Kestner the stoking was conducted with the most scrupulous attention, still the refrigerating action of a mass of water in the boiler must have impeded the union of oxygen and the combustible gases.

With regard to the relative proportion of carbon present in the form of carbonic oxide to that as hydrocarbons, I have already pointed out that experiments conducted as these necessarily were, cannot be expected to afford evidence on the point. I believe far more of the partially burnt carbon in the flue gases to be present in the form of hydrocarbons than as carbonic oxide, a view which is quite in accordance with the results already obtained by M. Scheurer-Kestner in the case of the effluent gases of boiler furnaces.

In order to afford some evidence as to the proportion of carbonic oxide to hydrocarbons, I append the result of an analysis kindly made by Dr. Percy Frankland on a typical sample of gas from an ordinary form of open fireplace, in which the feeding with coal was conducted so as to give as *imperfect* combustion as possible. The sample of gas was collected in the mercurial receiver to which I have already alluded (p. 34).

	By volume
Carbonic anhydride	0·70
Marsh gas (CH_4)	0·36
Hydrogen	0·29
Carbonic oxide	0·01
Oxygen	19·85
Nitrogen	78·79
	100·00

[1] *Mémoire sur la combustion*, par M. Petitpierre-Peillon, 1858. Chez MM. Lacroix et Baudry; quoted by Gruner. *Traité de Métallurgie*, t. 1, p. 436. Paris, 1875.

In this the relation *by weight* between the carbon as carbonic anhydride and that present as carbonic oxide and as hydrocarbon, is as 1,000 : 529. It will be observed, however, that the products of combustion being here diluted with an enormous volume of air, were present in relatively very small quantity, consequently this large proportion of unburnt and partially burnt gaseous products must not be taken as conclusively proved.

Proportion of Carbon wasted as Soot.

This, I need hardly observe, is a question of much interest. Earlier experiments have indicated the limits within which this proportion of soot will probably be comprised. M. Delezenne estimated in 1855[1] that the proportion of carbon that escaped combustion in this form might be taken at 5 per cent. of the total weight of fuel burnt in the grate, and that 6,320 kilogrammes of soot fell in twelve hours on the town of Lille. But, as Emile Burnat, quoting Payen, pointed out in a valuable paper on the combustion of smoke in boiler furnaces,[2] the amount of finely-divided carbon produced in a certain *lampblack* factory is only 3 per cent. of the coal burnt, and therefore the amount of carbon in ordinary smoke must be much lower.

In 1858 Mr. John Graham estimated[3] that very black smoke does not contain more than $\frac{1}{10}$ per cent. of the carbon of the coal burnt, and the accurate experiments of M. Scheurer-Kestner already quoted showed that in boiler furnaces the loss of carbon in the form of soot never exceeds 1 per cent. of the fuel burnt, while the mean loss is probably between $\frac{1}{2}$ and $\frac{3}{4}$ per cent. A case however is recorded, in which a coal containing 69 per cent. of carbon (burnt with an inadequate supply of air) thus lost an amount of carbon as soot equal to 2·03 per cent. of the fuel burnt.

As might be anticipated, the amount of soot is greater in the case of an open fire-place than in a boiler furnace, but the evidence afforded by the results of the tests made at the Exhibition, while possessing much interest, does not, unfortunately, render it possible to give a precise answer to the question, for the following reasons.

Some of the soot must have been deposited in the flue before it reached the point at which the withdrawing tube was inserted; and there is reason to fear that in the withdrawal of flue gas laden with soot through any form of slit or orifice in a tube, the gaseous and solid portions may not enter in exactly the ratio in which they exist in the chimney.

In many cases the flues were carefully swept before and after the trial, and the soot was collected and weighed. In an extreme case, in an open fire-place, no less than $2\frac{1}{4}$ per cent. of soot, compared with the fuel burnt, was found in the flue at the end of the trial. In the case of three close stoves of careful construction rather less than $\frac{1}{2}$ per cent. was found, while in some cases it fell to $\frac{1}{4}$ per cent., and in one case to $\frac{1}{20}$ per cent. Of course these numbers do not include the amount escaping into the air.

I may perhaps add that in a preliminary experiment made with an ordinary open fire-place connected to a chimney by means of a sheet-iron pipe 6 feet long and 9 in. diameter, 17 lbs. of bituminous coal were burnt in three hours, and no less than 0·61 per cent. of the fuel burnt was collected in the pipe in the form of soot, while the soot that passed into the chimney was not collected. This 0·61 per cent. of soot, after drying at 100° C., yielded, on distillation at 300° C., 12 per cent. of an oily strong-smelling mixture of hydrocarbons.

The Wallsend coal employed in the tests, an analysis of which is given on p. 38, gives, on distillation in a closed vessel, as coals of its class do, more than 30 per cent. of volatile matter. The products of the distillation of such a coal are very varied, and include many dense hydrocarbons, such as anthracene or chrysene, that would not be driven off at a temperature of 200° C. The figures given in column 8 will also include

[1] *Bulletins de la Société d'encouragement*, 1855, p. 473.
[2] *Memoires extraits du Bulletin de la Société Industrielle de Mulhouse*, p. 11. Paris, 1875.
[3] *Memoirs of the Literary and Philosophical Society of Manchester*. 1860.

such hydrocarbons. It would not have been safe to heat the asbestos sufficiently high to drive these all forward, for the point of inflammation of finely-divided carbon would soon have been reached; and, moreover, soot contains many at least of such hydrocarbons, which pass into the atmosphere and give to 'smuts' their disagreeable adhesiveness.

In some extreme cases the operation was continued for a sufficient time to give an abundant deposit on the asbestos plug, which, with its adhesive soot, was burnt in oxygen, and the resulting carbonic anhydride and water collected with the following result:—

	I.	II.	III.	IV.
Carbon	94·0	92·4	89·5	86·1
Hydrogen	5·2	3·3	5·1	4·2
Oxygen, Nitrogen, and inorganic matter (by difference)	·8	4·3	5·4	9·7
	100·0	100·0	100·0	100·0

Viewing the experiments generally, the increase in weight of the asbestos plugs was but small, varying from a barely perceptible increase to $\frac{8}{10}$ of a grain, but there could have been no serious error in the manipulative part of the work, as will be evident from an inspection of the amount retained by the asbestos plug when anthracite or coke was burnt, the small amounts of matter caught being probably mainly derived from the wood used in lighting the fires to start the combustion of the anthracite or coke.

If it be admitted that the asbestos plug has retained dense hydrocarbons that would not necessarily have passed into the air, I believe that the results calculated on the fuel would still be too high; I have therefore preferred to give the actual weighings exactly as they were obtained, for if they be taken in connection with the amounts of fuel burnt, they are at least comparative, and form a valuable adjunct to Mr. D. Kinnear Clark's scale of smoke-shade, which does not take into account the amount of fuel burnt. Future experiments, with the aid of a 'trompe' that will remove large volumes of flue gases laden with soot, must determine what the true amount of carbon lost as soot really is.

It is hoped, however, that the results will be of interest if they be taken in connection with the tests as to temperature and velocity of the effluent gases made by Mr. D. Kinnear Clark, the engineer by whom the mechanical tests were conducted, and I trust that the Committee will be satisfied that the scheme above described was the best that could be adopted in view of the fact that one hundred appliances were submitted for testing in the limited time during which the Exhibition was open. This series of chemical tests must be regarded as preliminary, as it will be very desirable to select certain of the stoves and grates, and to subject them in the same testing-house to a rigorous examination, including a complete analysis of the flue gases; for I consider that the work already done has merely rendered it possible to select certain typical appliances which deserve more detailed examination.

It will be evident that, in each case represented in the following Tables, the more perfect the combustion is, the smaller will be the numbers in columns 6 and 7. When certain special experiments have been made the considerable mass of figures gathered during the course of the tests, but not recorded in the Tables, may be expected to afford other important information as to the amount of waste in combustion and the way in which wasted heat is distribnted.

With respect to the actual conduct of the manipulative part of the work, I should state that the preliminary experiments were made by my assistant Mr. W. F. Ward, and, on his appointment as chemical adviser to the Tasmanian Government, the work was continued by Dr. E. J. Ball, on whom the burden of the manipulation has fallen, and to whose care and skill I am much indebted.

TABLE I.—RESULTS OF CHEMICAL TESTS OF GRATES AND STOVES.

CLASS I. *Open Grates, having ordinary bottom grids and upward draught.*

No. of test	No. of testing-room	Name of exhibitor	Description [1]	Nature of fuel	To every 1000 parts of Carbon as CO_2 there are of Carbon as $C_xH_y + CO$	To every 1000 parts of Carbon as CO_2 there are of Hydrogen free and combined with Carbon in the gaseous state	Weight of matter retained by asbestos in grains	Coal burnt per hour	Total average smoke shade (Mr. Clark)
1	2	3	4	5	6	7	8	9	10
								lbs. ozs.	
1	1	J. G. Gray .	Open grate, perforated loose back .	Wallsend .	76	84	0·045	3 1½	2·8
2	4	Barnard, Bishop & Barnards	The anthracite grate . . .	A mixture of Wallsend and anthracite .	95	83	0·045	2 1¼	1·92
3	4	The British Sanitary Co. .	Basket grate, inclosed in sheet iron and glass, heating air .	Wallsend .	143	51	0·045	3 0	4·7
5	2	M. Perret . .	Radiating fire-grate, firebrick lining and roof	Coke . .	45	77	0·030	6 3¾	0·
6	5	J. Wright & Co.	Hygienic ventilating stove . .	Wallsend .	49	65	0·070	6 5½	3·9
7	2	M. Perret . .	As before	Anthracite .	69	48	0·070	4 1¼	0·6
8	2	,, . .	As before	Wallsend .	234	111	0·200	7 2	·8
10	3	T. Potter & Sons	Open grate (hot-water pipes) air-heating	,, .	239	—	0·015	3 12	3·5
11	3	Perceval & Westmacott .	Parlour stove, for heating and for cooking, air heated . .	,, .	73	—	0·915	2 6½	2·6
15	4	T. Nash . .	Open grate, back down-draught to deposit soot	,, .	163	219	0·090	3 9	4·8
17	2	W. P. Taylor .	Fresh-air opening in hearth, fluted and perforated back . .	,, .	43	259	0·065	3 14½	2·6
18	2	The Radiator Range Co.	Combustion chamber at back of grate	,, .	76	30	0·040	3 10¾	—
19	5	A. B. Verrier .	'Comet grate,' firebrick lining, blower, heating fresh air, and drawing foul air from upper part of room . . .	,, .	168	29	0·060	3 13¼	3·7
20	5	,, . .	'Comet grate,' firebrick lining, blower, heating fresh air, and drawing foul air from upper part of room . . .	,, .	138	77	0·0	4 6	2·7
21	2	Rosser & Russell	Fireclay back, fluted, air heated .	,, .	39	52	0·110	3 6¼	1·9
23	5	G. Haller & Co.	Kohlhofer's hot-air stove, air-chamber above and at sides, up and down pipe flues . .	,, .	84	—	0·030	6 2½	3·0
24	4	Perceval & Westmacott .	Sanitary stove	,, .	54	17	—	3 9½	5·5
25	3	The Radiator Range Co.	As before	,, .	101	26	0·050	4 15¼	—
26	4	E. H. Shorland .	The Manchester grate, G. L. Shorland's patent. Air heated, and carried off in pipes . .	,, .	23	—	—	6 9	2·9
29	1	J. Wavish, plain grate .	Plain grates.	,, .	164	52	0·195	3 11	2·5
30	1	Do. with apparatus .	Air-cylinder in heart of fire . .	,, .	78	97	0·085	—	1·3

[1] See note to table, p. 45.

TABLE I.—RESULTS OF CHEMICAL TESTS OF GRATES AND STOVES—(*continued*).

CLASS II. *Open Grates, having solid floors, adapted for slow combustion and upward draught.*

No. of test	No. of testing-room	Name of exhibitor	Description	Nature of fuel	To every 1000 parts of Carbon as CO, there are of Carbon as C_xH_y + CO	To every 1000 parts of Carbon as CO, there are of Hydrogen free and combined with Carbon in the gaseous state	Weight of matter retained by asbestos in grains	Coal burnt per hour	Total average smoke shade (Mr. Clark)
1	2	3	4	5	6	7	8	9	10
								lbs. ozs.	
33	2	Barnard, Bishop & Barnards	Glow fire, brick slabs . . .	Wallsend .	90	79	0·085	2 2½	3·8
34	3	„ „ .	Bartlet grate, brick slabs . .	Wallsend and coke .	111	64	0·105	2 15	3·0
35	2	„ „ .	„ „ . . .	Wallsend and anthracite	205	108	0·050	3 5½	5·1
36	4	The Derwent Foundry Co.	Abbotsford grate „ . .	Wallsend .	275	95	0·135	2 8¼	4·2
38	2	Doulton & Co. .	Fire-place of firebrick slabs . .	„ .	48	70	0·040	3 15½	1·3
39	4	J. B. Petter .	Nautilus grate	„ .	83	66	0·070	2 4	3·9
41	5	F. Edwards & Son	Dr. Arnott's grate . . .	„ .	233	68	0·150	3 9	3·1
42	5	„ „ .	Downward burning grate . .	„ .	175	46	0·175	3 13¼	2·3
45	2	Frost & Winfield	Fire lumps and baffle roofs . .	„ .	77	58	0·045	3 8¾	4·4
46	3	Barnard, Bishop & Barnards	Glow fire	„ .	195	81	0·105	2 1	2·4
			CLASS III. *Open Grates, under-fed:—Supplied with fresh fuel beneath the incandescent fuel, with upward draught.*						
53	4	E. R. Hollands .	Under-feeding, with movable grate	Wallsend and cinders	103	67	0·015	2 9¾	2·5
55	3	Brown & Green .	Under-feeding, with tray in front .	Wallsend .	32	41	0·020	4 0½	2·1
56	4	W. S. Melville .	Under-feeding, shovel . . .	„ .	96	69	0·095	2 4¼	4·2
57	5	E. H. Shorland .	'Princess Louise,' G. L. Shorland's patent, under-feeding by shovel	„ .	114	41	0·055	2 7	3·0
58	3	Yates, Haywood & Co. .	Under-feeding, with movable grate	„ .	145	16	0·080	3 4	2·3
			CLASS IV. *Open Grates, to which fresh fuel is supplied from the back, or the sides, or hoppers.*						
60	4	A. C. Engert .	Coking box at back . . .	Wallsend .	164	67	0·105	2 13½	2·0
		HOPPER-FED.							
61	4	Musgrave & Co. .	'Ulster' register stove, hopper at back, heats air . .	Wallsend and cinders	187	103	0·050	3 5	2·2
62	3	The Coalbrookdale Co. .	Gassius grate, hopper-fed, solid bottom	Wallsend .	98	103	0·035	3 8	1·8
63	4	J. M. Stanley .	Downward draught, hopper-fed .	„ .	19	16	0·075	5 6¾	2·2
65	4	H. E. Hoole .	Hopper at each side, openings at bottom reflect on front .	„ .	78	79	0·065	2 2¾	2·5
67	4	Archibald Smith & Stevens .	'Wonderful grate,' hopper at back	„ .	96	39	0·075	5 0¾	4·3

Table I.—RESULTS OF CHEMICAL TESTS OF GRATES AND STOVES—(*continued*).

Class V. *Open Grates, having a downward, a backward, or a lateral draught.*

No. of test	No. of testing-room	Name of exhibitor	Description	Nature of fuel	To every 1000 parts of Carbon as CO_2 there are of Carbon as C_xH_y + CO	To every 1000 parts of Carbon as CO_2 there are of Hydrogen free and combined with Carbon in the gaseous state	Weight of matter retained by asbestos in grains	Coal burnt per hour	Total average smoke shade (Mr. Clark)
1	2	3	4	5	6	7	8	9	10
								lbs. ozs.	
68	4	The Coalbrookdale Co.	Kyrle grate, firebrick lining and floor, backward draught at bottom	Anthracite	42	28	0·005	1 11¼	0·0
69	3	Captain T. E. Clarke	Downward draught, air heated behind	Wallsend	77	141	0·040	2 9	1·8
71	4	The Derwent Foundry Co.	Smoke-burning register, Jobson's patent; downward and backward draught; tubular air-bars	Wallsend	49	53	0·035	5 4	3·2
72	3	M. Feetham & Co.	Ventilating dog grate, fire basket, downward draught	"	213	34	0·045	4 13½	1·2
73	3	" "	Hurst grate, downward and backward draught, air heated	"	243	—	0·035	3 4	1·4
74	3	" "	Do. do.	Anthracite	113	166	trace	2 3	1·3
76	4	Yates, Haywood & Co.	Redmayne's patent, backward draught, solid floor, air heated	Wallsend	119	48	0·135	4 8¾	4·7
77	4	" "	Redmayne's patent, backward draught, solid floor, air heated	Anthracite	49	59	0·0	3 11	0·3
79	3	Deane & Co.	Crane's anthracite grate, firebrick back and sides, downward draught	Wallsend	83	—	0·020	3 0¾	3·9
80	4	J. Moore	Draught backwards and downwards, air heating	"	38	66	0·060	3 4	2·5
81	2	Steel & Garland	'Kensington' back and side draughts into flue, air heating	"	125	13	0·090	3 9½	3·7
82	4	Clark, Bunnett & Co.	Ingram grate, backward draught, air heating	"	31	35	0·110	5 11¼	3·3
83	4	" "	Do. do.	Anthracite	16	41	0·005	4 15¾	0·0
84	2	Steel & Garland	'Kensington,' as above	"	177	219	0·010	6 3½	0·0
85	3	Brown & Green	'Luton' register grate, backward draught	"	78	43	0·005	2 9¼	0·0
86	3	J. T. Reeve	Reeve & Henry's smoke purifier, hob grate, backward draught, and filter chamber	Wallsend	128	174	0·045	1 6¼	1·6
88	2	T. E. Parker	Downward and backward draught	"	7	8	0·050	3 7¼	2·2
89	3	" "	The same grate, but less air admitted	"	44	60	0·035	3 2	2·4
90	3	J. Cornforth	Hollow air-bars and backward draught	"	95	59	0·130	4 13½	3·5
—	2	Deard	Down draught water heating apparatus	"	87	23	0·015	—	—
—	4	T. E. Parker	Down draught hot air	"	—	34	0·0	—	—

TABLE I.—RESULTS OF CHEMICAL TESTS OF GRATES AND STOVES—(*continued*).

CLASS VI. *Close Stoves.*

No. of test	No. of testing-room	Name of exhibitor	Description	Nature of fuel	To every 1000 parts of Carbon as CO_2 there are ofCarbon as $C_xH_y + CO$	To every 1000 parts of Carbon as CO_2 there are of Hydrogen free and combined with Carbon in the gaseous state	Weight of matter retained by asbestos in grains	Coal burnt per hour	Total average smoke shade (Mr. Clark)
1	2	3	4	5	6	7	8	9	10
								lbs. ozs.	
96	3	Musgrave & Co.	Slow combustion stove	Coke	61	37	0·000	2 3½	0·0
97	2	Rev. H. J. Newcombe	Tubular air warmer	Wallsend	49	20	0·060	3 7	2·0
99	3	C. Portway & Son	Tortoise stove, slow combustion heating and laundry stove	Coke	77	41	0·010	2 0⅓	0·0
101	2	Doulton & Co.	Spiral stove of stoneware, air heating	Hard steam	224	86	0·070	1 1	1·0
102	4	H. Hunt	'Economy' portable heating stove	Anthracite	375	58	—	2 8	0·3
104	4	Yates, Haywood & Co.	'Miser' stove, two pillars	Wallsend	110	39	0·175	1 13½	4·5
105	2	J. Cornforth	'Little Wonder' stove	"	7	39	0·035	3 12	0·7
106	5	R. W. Crosthwaite	Armstead's stove No. 3, delivering hot air to burn the gases	Anthracite	22	36	0·020	4 14½	0·5
111	5	W. Stobbs	Crystal ventilating grate	"	96	83	0·005	2 0½	0·8
113	5	H. Hunt	'Crown Jewel' base burner hall stove	"	114	66	0·005	2 6½	0·0
115	4	Van der Harst	Charcoal stove	Compressed Charcoal	180	33	—	0 11	0·0
117	3	Brown & Green	'Twin' stove	Hucknall bituminous coal	90	94	0·030	3 12½	3·1
118	3	J. F. Farwig & Co.	'Calorigen' stove, air heating	Wallsend	114	34	0·080	2 12½	1·2
120	5	J. Dunnachie	'Star' heating stoves, firebrick	"	34	94	0·030	5 0¼	2·5
122	5	W. Barton	'Premier' stove	Coke	26	—	0·025	3 10¾	0·0
123	5	F. Lönholdt	Anthracite stove, air heating [1]	Anthracite	132	100	trace	1 4¾	1·5
125	5	"	Anthracite stove, air heating [2]	"	19	43	trace	3 12½	0·0
126	5	H. J. Piron	Hot-air stove and ventilator	"	35	53	0·005	6 10	0·0
127	5	R. W. Crosthwaite	Armstead-Gregory stove	Wallsend	16	30	0·050	7 2½	0·5
129	3	Brown & Green	Close stove, with reversible draught	Hucknall	71	52	0·070	4 15¼	2·4
—	5	Churchill	Cold air	Wallsend	254	119	0·050	—	—
—	2	Deard	(Water coil)	Anthracite	99	74	0·005	—	—

[1] Slow combustion. [2] Rapid combustion.

NOTE.—The numbers and descriptions correspond with those given by Mr. Clark.

Under-feeding consists in placing cold fuel under that which is already ignited.

A *coking box* is a closed receptacle in which the fuel is gradually heated, the volatile products of the distillation being usually made to pass through the fire.

A *downward draught* causes the products of combustion and air to pass downward through the incandescent fuel, before entering the flue at or below the level of the grate.

A *backward draught* passes horizontally through the fuel, and enters the flue at a point either level with or below the surface of the fire, while a *lateral draught* enters the flue at the side.

Air heating implies that fresh air is heated by the appliance before entering the room. In some cases, such as Nos. 88, 89, 90, 105, and 106, attempts are made to effect the consumption of smoke by heating air before it mixes with the products of combustion in the flue.

In the so-called *base burner*, the draught is brought directly down from the fire-place of a close stove, and circulates round the base.

In *slow combustion* ignition of the fuel is maintained by the admission of as little air as possible.

REPORTS OF THE TESTING ENGINEER.

I. REPORT ON TESTS OF OPEN GRATES AND CLOSE STOVES FOR HEATING, 1881-1882.

(*Scale of Smoke-Shades.—See Frontispiece.*)

THE tests of open grates and close stoves were conducted in the testing-rooms in the grounds of Her Majesty's Commissioners at South Kensington.

The testing-rooms were built in a row, lying north and south. They are five in number, of which Nos. 1, 2, 3, and 4 are 15 feet square and 15 feet high to the eaves, with an additional elevation of 2 feet to the ceiling, formed within the truncated sloping roof. The total capacity of one of these testing-rooms is 3,600 cubic feet.

No. 5 room is at the extreme south end. It is 30½ feet long by 15 feet wide, and 15 feet high to the eaves, and has a capacity of 7,320 cubic feet.

The walls and the floor of each room are constructed of solid concrete 6 inches in thickness. Each of the smaller rooms has one window, 3 feet wide and 7½ feet high, and a doorway 3½ feet wide by 6½ feet high; both in the east or front wall. The doors of each pair of rooms are protected by a cabin enclosure having an outer door by which the influence of changeable weather could be in a great measure controlled. The chimneys, in concrete, one in each room, were built in the west wall. They were round, and averaged 8¾ inches in diameter. They were prolonged upwards by zinc pipes 6 inches in diameter; making a total height of 25 feet from the floor-level.

Observations were made for the temperature of the external air, the temperature of the test-room, the power of the grate or the stove for radiating heat, and the velocity of draught and temperature of the gaseous products in the chimney. Hygrometrical observations, also, were made for a time; but they were not considered of sufficient moment for the immediate purpose of the tests, and were not continued.

For noting the general temperature of the room, twelve thermometers were suspended from the four walls, three to each wall, at levels above the floor respectively 6 inches, 6 feet, and 14 feet. An attempt was made, in addition, to measure proportionally the radiating powers of the grates and stoves under trial; and, for this purpose, a stand was placed on the floor at a distance of 6 feet from the grate or stove, on which three pairs of thermometers were suspended, those of each pair back to back, at three different levels, respectively 1 foot, 5 feet, and 10 feet above the floor. One of each pair directly faced the grate or stove, and was exposed to the direct action of the radiated heat. The other indicated simply the temperature of the surrounding atmosphere of the room. The difference of the temperatures thus indicated was taken as a measure of radiated heat: not absolutely, of course, but relatively, as a means of testing approximately the comparative radiating powers of the exhibits. Observations of temperature were usually taken at intervals of half an hour.

The temperature in the chimney was measured by a mercurial pyrometer suspended in the chimney at a height of 10 feet above the floor-level; and the velocity of the draught was measured by a Biram's anemometer specially constructed and adapted to the situation, so that, whilst the wheel was inside the chimney, the indications could be read on the dial outside.

The fuels used were bituminous coal (Wallsend), anthracite, and coke. The composition of the coals is given in the Chemical Report by Professor Chandler Roberts, page 38.

For the purpose of noting the shades of smoke discharged from the chimney, smoke-coloured glass, of graduated tints, was tried; but ultimately a scale of ten shades of smoke was adopted, illustrated by the frontispiece; regularly increasing in density from a faint indication, or discoloration of the atmosphere, to a black-brown shade. The order-number of the shade was noted from time to time during each test, and the average of the numbers noted was taken as a proximate measure of the average density of the smoke.[1]

The duration of the tests extended usually to five hours, occasionally to six hours, and for still longer periods, commencing at or about 10 A.M. each day. Given quantities of wood and coal were weighed out to the article to be tested, at the commencement of the test, and the balances left uncharged and unconsumed at the end of the trial, were weighed back. Each exhibitor was allowed, for the most part, to conduct the test in his own way; and he or his deputy was present during the whole of the time of trial.

Grates are here distinguished from stoves, broadly as open fire-places or open grates *versus* closed fire-places or stoves. The use of the term 'stove,' originally applied to close fire-places, has been extended by exhibitors to open fire-places. To keep clear the significance of the classification, therefore, grates are described as open grates, and stoves as close stoves.

Fifty-nine open grates and thirty-three close stoves—ninety-two altogether—were submitted for testing. The open grates were divided into five classes. Close stoves were placed as Class 6. One hundred and thirty tests of open grates and close stoves were made and recorded.

TABLE II. CLASSIFICATION OF GRATES AND STOVES, WITH TESTS.

Class	Description of class	Number of grates and stoves	Number of tests
No. 1	Open grates, having ordinary bottom grids, and upward draught. (Table III.)	20	32
2	Open grates, having solid floors, adapted for 'slow combustion,' and upward draught. (Table III.)	11	20
3	Open grates, under-fed: supplied with fresh fuel beneath the incandescent fuel, with upward draught. (Table III.)	6	6
4	Open grates, to which fresh fuel is supplied from the back, or from the sides, or from hoppers. (Table III.)	6	9
5	Open grates, having a downward, or a backward, or a lateral draught. (Table III.)	17	27
	Open grates, total	59	94
6	Close stoves. (Table III.)	33	36
		92	130

[1] For the purpose of establishing communication between the observer of smoke-shades outside the building, and the attendant on the grate or stove within, an efficient scheme of telephonic communication was kindly prepared by Mr. C. Spagnoletti, Member of the Society of Electricians; and, though it could not be made available at the last Exhibition, it may do valuable service on future occasions.

DESCRIPTION OF THE GRATES AND STOVES THAT WERE TESTED.

CLASS I.—*OPEN GRATES HAVING ORDINARY BOTTOM GRIDS AND UPWARD DRAUGHT.*

No. 1. J. G. GRAY.—A perforated iron back is laid into an ordinary grate in a sloping position, so that the bottom of the grate is partly covered by it. Air from below is thus admitted into the fire, partly upwards, and partly forwards from the back. (Plate 1.)

No. 2. BARNARD, BISHOP & BARNARDS.—The 'Anthracite Grate;' having a lining of firebrick, sloping backwards; vertical bars in front, and a sliding blower. The bottom grid is inclined downwards towards the front.

No. 3. THE BRITISH SANITARY COMPANY.—'Carrick's Ventilating Stove Grate.' A radiating fire-grate, in which a fire basket is placed in an enclosed chamber, which forms the stove, constructed of sheet-iron at the back, and of glass panes at the front. Heat is radiated from the fire all around, and is transmitted through the glass casing into the room. Behind, it is transmitted to air in a chamber which is admitted at the bottom, and is discharged into the room at the upper part. It is said to be specially safe, and to be a preventive of 'blow-downs.' There is a glass door in front, which may be opened when required. The hot gases from the upper part of the apartment are drawn down through the fire-place. (Plate 1.)

No. 4. MICHEL PERRET.—'Radiating Stove,' to burn anthracite. Back, sides, and floor of firebrick; also a firebrick slab to form a roof, sloped slightly upwards so as to assist in radiating heat. The grate consists of bars forming the bottom and the front.

No. 5. MICHEL PERRET.—'Radiating Stove.' The same as No. 4, burning coke.

No. 6. J. WRIGHT & Co.—'Hygienic Ventilating Stove.' Draught passes upwards into an inner dome divided by a vertical partition, over which the gases pass and descend on the other side to the flue. The door and the back of the fire are surrounded by an air-chamber into which external air is admitted, and from which the warmed air is delivered into the room. (Plate 2.)

No. 7. MICHEL PERRET.—The same as No. 4, burning anthracite.

No. 8. MICHEL PERRET.—The same as No. 4, burning Wallsend coal.

No. 9. J. WRIGHT & Co.—'Hygienic Ventilating Stove,' as above, No. 6, smaller size.

No. 10. T. POTTER & SONS.—'Thermhydric Ventilating Grate,' surrounded by a water cistern at the back and sides. There are two groups of upright pipes, one at each side of the grate, into which, at the upper end, water passes from the upper end of the boiler, descending through the pipes to the lower part of the boiler, encased in a chamber supplied with air from the outside, which is heated, and passes off into the room. Excessive temperature of heated air is thus obviated. (Plate 2.)

No. 11. PERCEVAL & WESTMACOTT.—'Parlour Stove,' adapted for cooking and heating. The fire-place is of cast-iron let into a cistern for hot water, by which it is enclosed at the back and sides, with a clear interspace of half an inch. The gaseous products pass upwards to the right and the left through curved flue-pipes, called retort-flues on account of their form tapering upwards, and meet overhead on the way to the chimney. An oven is placed over the fire between the branched flues, and the

whole is enclosed in a rectangular casing, into which air is admitted, and from which it is delivered warm into the room. The upper part of the fire-place above the front bars may be closed with a pair of doors which act as blowers when the fire is lighted. Air is admitted to the fire through holes in the sides and the back, aud through the bottom grid, which is provided with a slide by which it can be closed as required. (Plate 2.)

No. 12. JAMES SMITH.—Anthracite or coke is burned with bituminous coal, which is charged into an open chamber at the back, and is gradually coked by the heat of the fire. The fire is made up with anthracite, and the coke of the previous day is laid upon it, high enough to cover the entrance to the coking chamber, whence the distilled gases pass through the burning fuel.

No. 13. W. POORE & Co.—'Triumph' Stove. Self-contained, with sheet-iron back. Upper part in front above the bars may be closed by a blower. Lined with fire-brick. The grate bars are set so closely together that the ash accumulates and forms a close bed acting as a solid bottom. (Plate 4.)

No. 14. W. POORE & Co.—'Triumph' Stove, as above.

No. 15. THOMAS NASH.—The draught is led from the upper part of the grate down outside the back by a pipe dipping into a box, whence it rises into the flue. Soot is deposited in the box.

No. 16. THOMAS NASH.—The same as No. 15.

No. 17. W. P. TAYLOR.—External air is introduced through a grating in the hearth in front of the fire to supply the draught. A fireclay back is formed with upright gills on the outer side, and is perforated to allow air passing up between the gills to enter amongst the burning fuel.

No. 18. THE RADIATOR RANGE COMPANY.—The 'Radiator' Fire-grate. A small rectangular combustion-chamber is hooked to the back of an ordinary grate, into which the gaseous products pass through openings at the lower part, covered by the burning fuel, whence they pass into the flue. Stray gases escape at the upper part into the flue. A small auxiliary chamber is formed on the front of this combustion-chamber to receive gases rising from the fuel, with air, and discharging them into the first chamber.

No. 19. A. B. VERRIER.—'Comet' Grate. Has a hood formed in two parts, which may be pulled down in front of the fire to quicken the draught. The draught is partly diverted through the back, which is of firebrick, into a chamber. This chamber is enclosed in an iron chamber, into which fresh air is admitted. The air is heated, and ascends into the room. Foul air is drawn off from the ceiling to the lower part of the grate and passes through the inner chamber, just noticed, into the chimney. (Plate 3.)

No. 20. A. B. VERRIER.—'Comet' Grate. The same as No. 19.

No. 21. ROSSER & RUSSELL.—Fireclay stove. All of firebrick, except a narrow section of grate, forming the front part of the floor. The back is deeply fluted. The draught passes up in the flutes, and is reversed downwards behind the back of the grate, whence it is carried off to the chimney. Fresh air is heated within the firebrick sides of the grate, which are hollow, and is delivered into the room.

No. 22. W. P. TAYLOR.—Air-opening in hearth in front of grate, to supply it, as in No. 17. Also air-opening into the fire through a brickwork back, between the bricks.

No. 23. G. HALLER & Co.—Kohlhofer's Hot-Air Stove. The products of combustion pass up and down a number of large pipes grouped within a sheet-iron casing, into which fresh air is admitted. The air is heated and delivered into the room. (Plate 5.)

No. 24. PERCEVAL & WESTMACOTT.—'Sanitary Stove,' designed to be of fire-tiles; but made of iron in this instance. An upright square stove, having an outer casing of

sheet-brass enclosing an air-space on all sides and on the top. A taper flue rises from the roof of the fire-place into the chamber formed above it, whence the gases escape through a nozzle at the back to the chimney. (Plate 4.)

No. 25. THE RADIATOR RANGE COMPANY.—The 'Radiator' Fire-grate. Same as No. 18.

No. 26. E. H. SHORLAND.—The 'Manchester' Grate, G. L. Shorland's patent. An ordinary grate, with firebrick lining. Narrow slit through back, 2 inches by ¼ inch, for air to enter into the body of the fire. Fresh air is admitted from below, over the back and sides, which are gilled, and rises into two pipes to supply other rooms with warm air.

No. 27. A. C. ENGERT.—The 'Solo' Grate. A grate of barrel form, occupying three fourths of a circle, in vertical transverse section, with quadrantal bars forming the front and part of the bottom. The back and the backward half of the bottom consist of a solid semicircular plate, which radiates the heat into the room. It is adjustable circumferentially so as to regulate the opening through the grate-bars, the access for air, and the rate of combustion. The grate is fed, at intervals, with fresh coal at the back, which is pulled forwards towards the front as required, to replenish the fire.

No. 28. R. H. GRIFFIN.—The sides, back, and floor of the fire-place are of iron, perforated, so that air enters into the fire-place on all sides. The back and flanks of the grate are of cast-iron, with shallow gills cast on the back surfaces, filled up flush with fireclay to 1 inch in thickness. The roof also is coated with fireclay. External air is admitted into a chamber behind the grate, and is warmed, and then delivered into the room at the upper part.

No. 29. J. WAVISH.—An ordinary grate was tested, for the purpose of comparison with the same grate when fitted with Mr. Wavish's system.

No. 30. J. WAVISH.—The 'Economiser.' The bottom of the grate of No. 29 was closed by an iron plate, on the centre of which a vertical hollow cylinder, perforated, was fixed. The air entering the cylinder from below was delivered heated into the heart of the fire. (Plate 6.)

No. 31. J. WAVISH.—Ordinary grate, as in No. 29.

No. 32. J. WAVISH.—The 'Economiser.' As in No. 30.

CLASS II.—*OPEN GRATES HAVING SOLID FLOORS, ADAPTED FOR 'SLOW COMBUSTION' AND UPWARD DRAUGHT.*

No. 33. BARNARD, BISHOP & BARNARDS.—'Glow-Fire,' Everitt & Barnard's Patent. Firebrick lining and floor. Air admitted from ashpit, passes up behind back, and through an opening over the fire, under a baffle or slab of firebrick, above the fire. The air is to mix with and consume gases rising from the fire. The gases and air pass out to the chimney through an opening at the front of the baffle. (Plate 6.)

No. 34. BARNARD, BISHOP & BARNARDS.—'Bartlet' Grate. Firebrick lining and floor. High and shallow. The front bars are vertical, sloping outwards at the lower part, so that fuel falls freely as it is consumed, and all the 'living fuel' is presented at the front. (Plate 7.)

No. 35. BARNARD, BISHOP & BARNARDS.—'Bartlet' Grate, as in No. 34.

No. 36. DERWENT FOUNDRY COMPANY.—'Abbotsford' Grate. Firebrick lining and firebrick floor laid upon the hearth. (Plate 10.)

No. 37. MARSHALL, WATSON & MOORWOOD.—'Harleston' Grate. The fire-place has

fireclay backs, sides, and floor. The stove is not recessed in the wall, but is placed in front of the chimney jambs, and so it projects into the room. It is surrounded by a canopy at the sides and the upper part, being a hollow projection of angular section, forming part of an air-chamber around and behind the grate. The external air enters the chamber at the level of the floor, and is warmed, and ascends and is delivered through apertures at the upper part into the room. (Plate 8.)

No. 38. Doulton & Co.—'Tile Grate.' Formed of fireclay, on a fireclay hearth. The fuel is laid on the hearth, guarded by a grid in front, which stands on the hearth, and can be placed in any position required. The back is sloped forward on the hearth. The fuel, piled up against the back, burns away mostly at the upper part, where the current of air strikes on the top of the fuel, on its way to the chimney. The heap of fuel partly projects into the room; and heat is radiated freely. The flanks of the fire-place are splayed, so as to further promote radiation of heat. (Plate 9.)

No. 39. J. B. Petter.—'Nautilus' Grate. Placed in the chimney recess. The floor and the back form, in cross section, a continuous curve, and are of solid fireclay. Curving upwards, they form a convolution, which is continued in metallic plate, whence the gaseous products pass off horizontally to the right and the left, and meet in the chimney. (Plate 10.)

No. 40. Steel & Garland.—'Wharncliffe' Grate. The stove is set in front of the chimney jambs, and is formed with a hollow canopy, like that of No. 37, made with gills on the inner face, to augment the warming surface. Fresh air is admitted into a narrow air-chamber at the back, and is delivered through openings at the upper part into the room. (Plate 11.)

No. 41. F. Edwards & Son.—Dr. Arnott's Grate. Slow combustion. Fire is made up for the day on a grid, movable vertically by a screw motion. It is lit at the top, and burned downwards, and is elevated as required, so as to maintain one level of fire.

No. 42. F. Edwards & Son.—'Smoke-preventing Slow-combustion Grate.' Solid floor. The fire is made up for the day, lighted at the top, and burned downwards. A movable blind is in front, enclosing the fuel, and lowered as required, to admit air for burning down the fire. When coal is very dirty, a grid is placed as a bottom. Air is heated behind the grate, and delivered into the room at the front.

No. 43. F. Edwards & Son.—'Slow-combustion Grate.' The same as No. 42.

No. 44. J. B. Petter.—'Nautilus' Grate. The same as in No. 39.

No. 45. Frost & Winfield.—The grate is made with firebrick lining and floor; also firebrick roof slab, or baffler, nearly horizontal. Cold air from the ashpit ascends behind the back, and passes through holes in the back—at the bottom into the fire, and at the upper part above the fire. These horizontal currents meet currents of air from the front—through the fire and above the fire—for the purpose of effecting the combustion of the fuel, as well as of the gases which rise from it. The gaseous products above the fire pass up partly through holes in the baffle slab, and partly round the front of the baffle, into the chimney.

No. 46. Barnard, Bishop & Barnards.—'Glow-Fire.' The same as No. 33.

No. 47. T. Mitchell.—Common grate, lined and floored with fireclay. The back and the side linings were formed with an overhang at the upper part.

No. 48. T. Mitchell.—The same common grate, in ordinary condition, to compare with No. 47.

No. 49. T. Mitchell.—The same common grate, lined with fireclay, overhung, as in No. 47, with open grid bottom.

No. 50. T. MITCHELL.—The same common grate, lined and floored with fireclay. The back and the sides were formed straight, without overhang.

No. 51. T. MITCHELL.—The same common grate, lined with fireclay, flat as in No. 50, with open grid bottom.

No. 52. T. MITCHELL.—The same common grate, in ordinary condition, as in No. 48.

CLASS III.—*OPEN GRATES, UNDER-FED: SUPPLIED WITH FRESH FUEL BENEATH THE INCANDESCENT FUEL.*

No. 53. E. R. HOLLANDS.—Under-fed Grate. A movable grid, to uplift the burning fuel, and make room for fresh fuel beneath it; after the fresh fuel is laid in, the movable grid is withdrawn, and the fuel settles down on the permanent grid. (Plate 11.)

No. 54. H. THOMPSON.—'Smokeless Stove.' An ordinary grate, having a solid cast-iron bottom. The front is movable upwards. To stoke, a separate plate is introduced at the bottom under the fuel; the fuel and the front of the grate are raised together by a simple lever-action, and space is made for fresh fuel delivered from a shovel. The plate is then withdrawn, and the first position is resumed.

No. 55. BROWN & GREEN.—'Smoke-consuming Register Stove.' Fuel is placed on a trough at the front of the grate, level with the bottom, and is pressed into and below the fire by means of a hoe-shaped feeder. The back of the grate is inclined forward at the bottom, so as to narrow the area of the grid, and cause the fuel to slide forward as it burns away. The back is slotted, to admit air to the fire. (Plate 12.)

No. 56. W. S. MELVILLE.—A taper-pointed hollow shovel, to supply fresh fuel beneath the fire. The fuel is contained in the body of the shovel, and is pushed into the fire by a piston inside.

No. 57. E. H. SHORLAND.—'Princess Louise,' G. L. Shorland's patent. Fire-brick lining and floor. Under-fed, by means of a taper box-shovel, to admit which the front bars slide upwards.

No. 58. YATES, HAYWOOD & CO.—The lower part of the grate is movable, and is removed for feeding fresh coal from below, whilst the incandescent fuel is temporarily upheld. The bottom is then replaced, and the temporary support withdrawn, and the fuel settles down together.

CLASS IV.—*OPEN GRATES, TO WHICH FRESH FUEL IS SUPPLIED FROM THE BACK, OR THE SIDES, OR FROM HOPPERS.*

No. 59. A. C. ENGERT.—An ordinary grate, having a coking box at the back, filled with fresh coal, which is pushed gradually into the body of the fire, as required, by means of a movable plate; and the gases are gradually distilled and consumed. (Plate 12.)

No. 60. A. C. ENGERT.—Grate with coking box. Same as No. 59.

No. 61. MUSGRAVE & CO.—'Ulster' Smokeless Stove Grate. Sides and floor of firebrick. A hopper is constructed at the back of the fire, to hold a supply of coal, which descends as it is burned away, and passes into the fire-place at the back through a large opening at the lower part of the hopper. The fuel is loosened as required, and

pushed into the fire by means of a lever. Fresh air is admitted at the back of the grate, and is delivered warm into the room. A perforated rolling curtain, made to slide up and down, acts as a blower, whilst permitting the fire to be seen through it. (Plate 13.)

No. 62. THE COALBROOKDALE COMPANY.—'Gassius' Grate. The floor is solid, of firebrick. The lower part of the front consists of three horizontal bars, and the upper part of twelve vertical firebrick slabs, ⅜ inch thick, presented edgewise. The bars are enclosed by mica plates in front. The fuel is fed from a hopper receptacle at the back, at a low level. The combustible gases rise between the fire-tiles.

No. 63. J. M. STANLEY.—The grate is fed from a hopper at the front. The sides and back of the grate are of firebrick. The gases are burned as they are distilled into the incandescent fuel below. The draught is carried through four openings at the bottom—two through the back, and one at each side—whence it passes through tubes or pillars, by which they are conducted into adjoining rooms for heating purposes. Fresh air is warmed behind the grate and delivered into the room. (Plate 13.)

No. 64. J. M. STANLEY.—Same as No. 63.

No. 65. H. E. HOOLE.—'Radiating and Reflecting Grate.' Coal is deposited in a small hopper at each side, forming hobs, and passes through an opening at the lower part of each hopper into the fire, occasionally assisted by the use of the poker. The fire-place is encircled by a polished reflecting surface of the form of a truncated cone. (Plate 13.)

No. 66. ARCHIBALD SMITH & STEVENS.—Russell's 'Wonderful' Grate. Fresh coal is supplied from a hopper above the grate, at the front, passing backwards and downwards, and delivering the coal at the back of the grate. The grate stands forward, so as to present two open sides as well as the front, for radiation. (Plate 15.)

No. 67. ARCHIBALD SMITH & STEVENS.—'Wonderful' Grate. Same as No. 66.

CLASS V.—*OPEN GRATES, HAVING A DOWNWARD, OR A BACKWARD, OR A LATERAL DRAUGHT.*

No. 68. THE COALBROOKDALE COMPANY.—'Kyrle' Grate, Parker's patent. Firebrick lining and floor. The draught is mostly downwards through an opening at the lower back corner into the flue. There is also a backward draught through an opening in the back, just above the fire, which meets the backward draught ascending from the bottom. (Plate 14.)

No. 69. CAPTAIN T. E. CLARKE.—'Ventilating Grate.' Downward draught through the bottom, returning through a pair of pipes, one at each flank, into the chimney. External air is admitted behind the grate, in a chamber enclosing the back of the grate and the pipes, and is delivered warm into the room. Or, air from the room may be passed in and heated.

No. 70. CAPTAIN T. E. CLARKE.—'Ventilating Grate.' Same as No. 69.

No. 71. THE DERWENT FOUNDRY COMPANY.—Jobson's 'Smoke-burning Register,' having firebrick lining. The draught ascends, and is reversed down a pocket flue at the back, at the lower end of which it meets with currents of air passed from the front through tubular fire-bars, and there heated, for burning the smoke. The draught also, in part, descends between the fire-bars, and meets and mingles with the descending draught at the back, with the air from the fire-bars. The united currents pass off to the chimney by a back flue, corrugated and gilled, in which the draught is regulated by means of a swing damper. Fresh air is admitted into a warming chamber at the back

of the grate, which is gilled, and enclosed with sheet-iron; and is passed off into the room at the upper part.

No. 72. M. FEETHAM & Co.—'Smoke-consuming Dog-Grate,' on the Hurst principle. (See No. 73.) Hollow gill-cheeks, with a nozzle at the back. Downward draught through the sides to the under side of the grate.

No. 73. M. FEETHAM & Co.—The 'Hurst' Grate. Designed for slow combustion: hollow iron back and cheeks made with horizontal gills, to form a zigzag course for the draught upwards within them. The draught passes out by three ways: downwards, and principally, through the grate, into the ashpit, which is closed, whence it passes off by an opening through each cheek, and upwards within the cheek. The stray smoke passes off through the back just above the fire, and descends to the bottom, where it is split, and whence it rises right and left to the upper part of the grate. Here the three currents meet, and they pass to the chimney. Fresh air is admitted behind each side at the lower part, and ascends to the upper part, where it is discharged into the room. The backs of the sides are made with upright gills to facilitate the warming of the ascending currents of fresh air.

No. 74. M. FEETHAM & Co.—The 'Hurst' Grate. Same as No. 73.

No. 75. M. FEETHAM & Co.—The 'Hurst' Grate. Same as No. 73.

No. 76. YATES, HAYWOOD & Co.—Redmayne's Grate. Firebrick sides, back, and floor. The draught passes horizontally through the back and sides, which are perforated, and it descends into a smoke-box below the floor; thence it passes up through pipes into the chimney. The pipes and the back are enclosed in a chamber, into which fresh air is admitted. The air is heated, and it passes into the room at the upper part. (Plate 21.)

No. 77. YATES, HAYWOOD & Co.—Redmayne's Grate. Same as No. 76.

No. 78. DEANE & Co.—Crane's Anthracite Grate: Firebrick back and sides. Downward draught through openings in the sides into the ash-box; thence upward behind the back to the chimney. An opening in each side, at the upper part, to let off stray gases, which are led down behind the sides into the common flue. (Plate 15.)

No. 79. DEANE & Co.—Crane's Anthracite Grate. Same as No. 78.

No. 80. JOSEPH MOORE.—Ordinary Grate. The draught is principally taken downward through the bottom grid. Just above the fire, the draught also passes through a slot in the back into the flue. The air of the room enters at the bottom behind the grate, through the sides, and is delivered warm into the room at the upper part. A sliding blower is in front. (Plate 16.)

No. 81. STEEL & GARLAND.—'Kensington' Grate. Firebrick sides, back, and floor. The sides and back, suspended from the upper part, hang half-way down into the fire-place. Gases pass direct from the fire under and behind the sides and back, and are carried behind an inner plate to the space below the floor of the fire-place, whence they move up behind the grate to the chimney. Fresh air is heated in a chamber at the back, and is delivered into the room. (Plate 16.)

No. 82. CLARK, BUNNETT, & Co.—Ingram's 'Kaio-Kapnos' Grate, has firebrick lining and floor. The gases pass through the back and downwards, and under the floor of the grate to the front; thence under a horizontal partition plate, to the back, and up the chimney. The draught may be partially or wholly carried directly upwards. (Plate 17.)

No. 83. CLARK, BUNNETT & Co.—'Kaio-Kapnos' Grate. Same as No. 82.

No. 84. STEEL & GARLAND.—'Kensington' Grate. Same as No. 81.

No. 85. BROWN & GREEN.—'Luton' Register Grate, to burn anthracite. Firebrick back and sides; holes through the back half-way up, covered with the fuel, through

which a back draught is conducted. The bottom grid is sloped upwards towards the back, reaching up to a flue passing through the back just above the fire. A few small holes at the upper part for stray gases to pass away into chimney. (Plate 17.)

No. 86. W. I. Henry.—Reeve & Henry's 'Smoke-Purifyer' ('Calpean'): Hob-grate. The bottom grid is closed by a sheet-iron plate applied below it. The draught is direct, through slits in the back, into a filter-bed or box containing iron turnings, which, becoming red hot, consume the smoke. The burnt gases pass to the chimney. A shallow chamber is constructed below the bottom plate, in which external air, admitted at the back, is warmed. The warmed air passes off into the room by side openings. (Plate 16.)

No. 87. W. I. Henry.—Reeve & Henry's 'Smoke-Purifyer': Hob-grate. Same as No. 86.

No. 88. T. E. Parker.—The 'Vencedor' downward-draught fire. Has a solid bottom, on a plate formed with gills. Air is admitted below the plate, passing between the gills, and is heated. It passes to the back, and meets incandescent fuel at the back angle of the fire-place, which is open there. The current passes into a tapered chamber of firebrick. The gases which rise from the top of the fire are drawn over the back plate through a slit into the tapered chamber, the gases being heated by the back plate in their descent. The currents are united in the taper chamber, and pass through a narrow aperture to the chimney. (Plate 16.)

No. 89. T. E. Parker.—The 'Vencedor' Grate. Same as No. 88.

No. 90. J. Cornforth.—The fire is covered by a horizontal hood, under which the gases pass to the back. There are hollow bars through which air from the front is passed and is heated. The air is delivered at the back, where it meets the gases from the fire, to consume the smoke.

No. 91. W. I. Henry.—Reeve & Henry's 'Smoke-Purifyer' ('Calpean'): Register Grate, adapted as in No. 86.

No. 92. Deane & Co.—Crane's Anthracite Grate. Same as No. 78.

No. 93. W. Lawrence.—There is a combustion-chamber at the back of the fire-place, into which the gases and air are passed. Incandescent fuel from the fire-place is deposited here by gravitation, and maintains the temperature for combustion, as the gases pass over and above it. Fresh coal is lodged in shoots, one at each side of the grate, opening at the lower part into the fire-place. The coal is distilled gradually, and the gases are passed into the fire and consumed.

No. 94. The Wilson Engineering Company.—An ordinary grate, to the back and flanks of which covering plates are applied, enclosing shallow air-spaces, extending from the bottom grid to the upper part of the grate. These air-spaces are open to the fire at the lower part, forming flue-ways, so that, when the register is closed, the draught enters them direct from the fire, and passes upwards to the chimney. The plates are made with gills, so that the gases follow a zigzag course upwards; and as the plates become highly heated, the ascending gases are maintained at a high temperature, for the purpose of consuming smoke. At the same time, heat is radiated from the plates.

Class VI.—*CLOSE STOVES.*

No. 95. C. B. Gregory.—'Smoke-burning Furnace,' enclosed in a cubical casing of cast-iron, lined with firebrick. The fresh fuel is charged into a steeply inclined hopper of firebrick, and falls upon a horizontal grate. Air is admitted to the fuel at the lower part of the hopper, and through the grate. Air is also admitted at the front;

it passes along the sides in contact with and heated by the hopper, and is discharged at the throat of the furnace at the back, in two streams, from opposite sides, meeting and mingling with the combustible gases from the fire. Complete combustion is thus effected. (Plate 19.)

No. 96. MUSGRAVE & Co.—Slow-combustion Stove. An upright cylinder of cast-iron, lined and floored with fireclay, having an ash-door at the bottom and a feeding-door at the top. The gases rise to the top and pass over the back into a descending flue, whence the current turns under a partition into an ascending flue, whence by a nozzle at the upper part it passes into the chimney. Fresh air is admitted at the lower part into a casing enveloping the cylinder and the flues. It is warmed as it ascends in contact with their surfaces, and escapes into the room at the upper part. (Plate 20.)

No. 97. REV. H. J. NEWCOME.—'Tubular Air-warmer.' Consisting of a group of horizontal pipes, connected with a close stove, from which the gases pass through the pipes. The soot is swept from the tubes into a reservoir. The air of the room or hall circulates around the pipes and becomes heated. (Plate 22.)

No. 98. B. J. KLINGENBERG.—Reck's Stove. An upright cylinder of cast-iron, enclosing a stove at the lower part, from which the gases ascend into a cylindrical flue, which is divided by a vertical partition, so that the draught passes up one side and down the other side of the partition, and passes out at the lower part of the flue-pipe. The stove and the flue-pipe are surrounded by fresh air introduced from below, which passes up and is warmed as it goes, and is discharged at the top of the casing. The body of the fire-place is enclosed in an envelope, with a narrow air-space between them; thus it is provided that the air to be warmed is not liable to be scorched by contact with over-heated iron.

No. 99. C. PORTWAY & SON.—'Tortoise' Stove, for slow combustion. A plain upright eight-sided stove, lined and floored with fireclay slabs. The fuel burns on the tile floor. There is an ashbox-door at the bottom, and a feeding-door at the top. The products of combustion rise to the upper part, whence they pass off by the nozzle to the chimney. (Plate 21.)

No. 100. THE DERWENT FOUNDRY COMPANY.—Jobson's 'Slow-combustion Gill-Stove.' Consisting of a number of open frame-like diaphragms laid side by side, and bolted together with front and back plates, forming a close stove with twenty exterior gills. It is divided into two unequal parts by a vertical partition, the larger of which is the fire-place, having a grid at the lower end and an ashbox. The draught is passed directly upwards for lighting up, and is next reversed, passing downwards through the grate, and upwards through the smaller compartment to the flue. The gases are met by a current of air issuing from the partition, which is hollow, to be consumed. (Plate 18.)

No. 101. DOULTON & Co.—'Spiral Stove' of stone-ware, consisting of several superposed rings forming chambers. The fire-place is formed in the lowest chamber, whence the gaseous products rise into and pass round each ring in succession; they pass off from the uppermost ring to the chimney. The rings are supported one on the other by perforated edges, through which air enters and becomes heated. The heated air passes into and flows up the central cylindrical shaft, whence it is discharged through a perforated covering. Air also is admitted into a compartment next the fire-place, and, being there heated, joins the other currents of air and escapes at the top.

No. 102. HARRY HUNT.—'Economy' Portable Stove, for burning anthracite, coke, or other smokeless fuel. The body is a cylinder of cast-iron, on a cast-iron base to hold the ashpan. The fuel is burned in a cylindrical fire-pot of fireclay, having a grid at the bottom, which can be shaken so as to let drop the ash, or tilted so as to let fall the whole

of the fire into the ashpit. The charging door, near the upper end, is made with panes of talc, through which the fire can be seen. The gaseous products pass off direct by the nozzle at the back into the chimney. When day and night service is required, a hopper for fuel is provided, placed over the fire-pot. The supply of air for combustion is regulated by slides at the hearth.

No. 103. HARRY HUNT.—'Economy' Base-Burner Hall Stove, for smokeless fuels. The body is a cylinder of cast-iron, on a cast-iron base to provide the base flues. The fuel is burned in a cylindrical fire-pot of fireclay, like that of the 'Economy' Portable Stove, having a tilting grid at the bottom. The fuel is filled into an upright hopper above the fire, whence it is supplied by gravitation as the fire burns away. The gaseous products pass over the top of the fire-pot, and descend at each side into the base of the stove, beneath the fire-chamber, within which they circulate. Thence, they pass off by a flue-pipe to the chimney. The charging door is formed with panes of talc.

No. 104. YATES, HAYWOOD & CO.—The 'Miser' Stove. An upright cast-iron cylinder, lined with firebrick. The lining is double at the back, forming a descending flue for the gaseous products, which pass into the flue through perforations at various levels. The gases pass to the right and the left at the bottom, and ascend through two upright pipes or pillars, one at each side, into an upper chamber, whence they are drawn off through a nozzle into the flue. (Plate 22.)

No. 105. JOHN CORNFORTH.—The 'Little Wonder.' An oblong rectangular stove of cast-iron. The fire-bars are hollow, and are traversed by air which is heated on its way through, and is delivered upwards at the bridge, so as to meet and mingle with, and consume the combustible gases passing from the fire.

No. 106. R. W. CROSTHWAITE.—Armstead's Stove, No. 3. An upright cylinder of cast-iron, grated at the bottom, and lined with fireclay at the fire-place. The fuel is charged at the top. The burning gases ascend, make a circuit in a spacious annular flue of cast-iron round the upper end of the cylinder, and proceed thence to the chimney. The area of radiating surface is doubled by the annular flue.

Nos. 107, 108, 109, 110. R. W. CROSTHWAITE.—Armstead's Stoves, Nos. 1, 2, 4, and 5, as in No. 106.

No. 111. W. STOBBS.—'Crystal' Ventilating Grate, for anthracite and coke. It is half-round in plan, and projects into the room. A circular fire-basket, grated all round, has a movable flat grid for the bottom, which can be shaken to clear out ash, or drawn aside to let fall the fire. It is fed with fuel from a circular hopper, grated all round. The whole is placed within a cast-iron case made with panes of talc to show the fire. The products of combustion pass upwards and enter the hopper at the upper part above the fuel, passing through the grating of the hopper. Thence they descend through two flues, one at each side of the hopper, to the base, whence they radiate heat at each side, and pass off to the chimney. Fresh air is admitted at the base into the surrounding casing, whence it is delivered warm into the room. (Plate 22.)

No. 112. DOULTON & CO.—'Top-Feeding Stove,' in stoneware. A square upright stove, divided by a vertical partition, forming at one side a hopper for the charging of coal, which gradually falls to replace the fuel consumed. The gaseous products pass through an opening near the base of the partition into the other compartment, where they meet an additional supply of air; and from the upper part of this compartment the gases pass into the flue. It is designed thus to consume all the smoke. Fresh air is admitted into the lateral warming spaces, from the upper parts of which it escapes into the room. (Plate 23.)

No. 113. Harry Hunt.—'Crown Jewel' Base-Burner Hall Stove, for burning anthracite and other smokeless fuels. The fuel is burned in a hemispherical fire-basket of cast-iron in three pieces: the body and the grid-saucer, with a sliding plate at the bottom. The body is grilled all round at the lower part for the admission of air, in addition to the air admitted through the grid. The plate may be shaken, or it may be withdrawn, to let fall the ash, or the whole of the fire, into the ashpan. The draught passes over the edge of the fire-basket, and descends to the base, where it circulates below the ashpan prior to passing off to the chimney by a back flue. (Plate 24.)

No. 114. Harry Hunt.—'Hygiene' Ventilating Stove, for burning smokeless fuel: resembling an ordinary grate, enclosed with talc windows. The fuel is burned in a shallow circular fire-pot of cast-iron, in two pieces, of which the upper part or body is indented at the lower part, to form a grill for admitting air all round to the fuel. The lower part is a circular grid on which the fuel rests. It can be shaken or tilted, when required, so as to let fall the ash or the whole of the fire into the ashbox. The fuel is fed from a round hopper above the fire. The draught passes over the edge of the fire-pot, and descends through a number of pipes to the base, where it circulates below the fire-chamber; thence passing by an upright flue-pipe to the chimney. The upright pipes, with the flue-pipe, are encased in a hot-air chamber at the back. Fresh air is admitted into this chamber below, and is heated in passing upwards around the pipes and the escape flue-pipe, all of which are coated with fireclay. The air escapes through a grating at the upper part into the room. (Plate 24.)

No. 115. Van der Harst.—Charcoal Stove. A cylindrical cast-iron stove, for burning charcoal briquettes. No flue-exit is provided for the gaseous products.

No. 116. Steel & Garland.—Four-pillar Stove (Redmayne's). The same in design as the 'Miser,' No. 104. There are four pillars or pipes, instead of two, as in the 'Miser.'

No. 117. Brown & Green.—'Twin' Smoke-consuming Stove, or Double-heating Stove. In one stove the fire is made with a downward draught through the fire. The gases are conveyed into the second stove, thence to the chimney. The second stove has an inside lining enclosing an 'air-jacket,' into which air enters at the bottom, escaping warmed at the upper part. (Plate 25.)

No. 118. J. F. Farwig & Co.—'Calorigen' Slow-combustion Stove. Within a cast-iron cylindrical casing, a cylindrical fuel-chamber of fireclay is placed eccentrically, filled with coal, which is lit from the bottom, to which the supply of air is regulated. A fresh-air chamber is placed beside the fuel-chamber, overlapping it sidewise, in which external air, admitted below, is warmed; the air being discharged at the upper part. (Plate 26.)

No. 119. The Sunlight Stove Company.—'Sunlight' Heating-Stove. The fuel is burned in a brazier or fire-basket grated all round it, surmounted by a 'heat-chamber,' like a small table, in which 'the heat can spread,' having a baffle plate to prevent the direct egress of the gases to the chimney. Fuel is supplied through the side of the heat-chamber, which is fitted with sliding perforated doors. A movable ashbox is fitted below the brazier.

No. 120. J. Dunnachie.—'Star' Heating-Stove. An upright square stove of fire-brick, in an open cast-iron casing. It is divided diagonally into two compartments by a partition, over which the gases pass and descend on the other side of the partition; they then pass off into the flue. Air for combustion is admitted behind the lower

part of the partition, becoming heated, and passing through holes in the partition into the fire-place. (Plate 27.)

No. 121. DOULTON & Co.—Ordinary large Stove, in stoneware, ventilating. The fire-place is formed at the bottom, whence the gaseous products pass out into the body of the stove. The gases are caused by baffle-plates suitably placed to take a zigzag course upwards, and thus pass off to the chimney. Fresh air is introduced at the bottom, and ascends through two upright square pipes into an air-chamber at the top, from which it passes out laterally. (Plate 26.)

No. 122. W. BARTON.—The 'Premier' Stove. Cylindrical, upright, and built up of sections, without bolts or screws; easily mounted and dismounted. It is formed with numerous gills on the outside for the conduction and rapid dispersion of heat. The deadplate and grate, in one piece, can be withdrawn through the lower doorway. (Plate 28.)

No. 123. FRANZ LÖNHOLDT—(Agents, Rosser & Russell, London).—Anthracite Stove, base-burning. It is an upright stove, of cast-iron, having panes of talc to show the fire. The fire is contained in a circular basket, into which the fuel is supplied from an upright cylinder or hopper above the basket. It has a bottom grid which is movable for shaking out ash and cinders, without causing dust, as the ash falls into a pan enclosed beneath the grate. The grate-basket is isolated and does not touch the inner casing in which it is enclosed. Air from the room, as well as fresh external air, circulates through upright tubes at the sides of the grate, where it is heated and whence it passes in upward streams into the room. Foul air from the room is passed through a ventilator into the smoke-flue before it enters the chimney. The products of combustion are drawn downwards, and they circulate in the base of the stove before they pass to the chimney. The supply of air for combustion can be regulated or shut off. By this means, with the admission of air into the flue, the fire in the stove can be regulated to burn several days and nights continuously, with one supply of fuel. If charged with fuel at intervals of from twenty-four hours to forty-eight hours, the stove burns continuously throughout the winter. (Plate 27.)

No. 124. FRANZ LÖNHOLDT.—Anthracite Stove. The same as for No. 123.

No. 125. FRANZ LÖNHOLDT.—Anthracite Stove. The same as for No. 123.

No. 126. H. J. PIRON.—Ventilating Stove, burning anthracite. This is an upright cast-iron cylinder, enclosing an inner cylinder, of which the lower part is occupied by the fire-place, and the upper part is narrowed to a swan-neck form conducting the gaseous products to the flue-pipe. The fire-place is of iron, with a grid at the bottom. The air required for burning the fuel is drawn from the apartment; and the same air is allowed to pass upwards outside the fire-pot, to meet and mingle with the gaseous products, and to pass off with them. The interspace between the outer and the inner cylinder is occupied by fresh air admitted at the lower part, which is heated as it ascends and passes into the room at the upper part of the outer cylinder. A pan of water is placed beneath the fire-pot, and water is lodged on the top of the stove for evaporation into the room. The casing is lined with a non-conducting substance.

No. 127. R. W. CROSTHWAITE.—Armstead-Gregory Stove. A combination of Armstead's Stove (No. 106) and Gregory's Stove (No. 95). (Plate 28.)

No. 128. BROWN & GREEN.—'Albion' Stove. Upright cylinder of cast-iron, lined with firebrick for part of the height. The grate may be withdrawn by the ash-door, and the ash falls to the bottom. The nozzle or flue-pipe at the upper part is guarded by a grid to prevent fuel lodging in it. (Plate 28.)

No. 129. BROWN & GREEN.—Cylindrical Stove, with reversible draught; fitted with valves for this purpose.

No. 130. J. DUNNACHIE.—'Star' Heating-Stove. The same as No. 120.

ADDENDA.

E. KAULBACH exhibited the 'Phœbus' Reversible Grate. The basket is cubical, made of ornamental grating, admitting air to the fuel at every side. The basket is suspended on two trunnions, which are supported by carriages that travel on rails. Thus, the fire can be brought forward, or pushed back, and the temperature of the apartment regulated accordingly. A simple mechanical arrangement, concealed in one of the carriages, and consisting merely of a pinion and screw, enables the basket to be instantly reversed after re-feeding. The fire is lighted from the top and burns downwards, consuming its own smoke, as shown by the subjoined result of a test which took place in the open arcade, on March 7, 1882. The grate was three hours under a partial test, for smoke-shade; during the first hour there was no visible smoke, afterwards the smoke-shade varied from No. 1 to No. 2; and the average smoke-shade for the whole time was 1·13. There were no means, on this occasion, of testing for temperature.

J. & J. MCMILLAN'S Under-feeding Grate was tested in connection with their kitchener, which is noticed at page 101.

RESULTS OF THE TESTS OF OPEN GRATES AND CLOSE STOVES.

The results of the tests of grates and stoves are embodied in the large Table III., following, comprising the results of 130 tests, effected in 59 open grates and 33 close stoves. They are placed in six classes, in chronological order for each class, comprising a period of three months, from December 1881 to March 1882.

TABLE III.—RESULTS OF TESTS OF OPEN GRATES

CLASS I. *Open Grates, having ordinary*

No. of test	No. of testing room	Date	Name of exhibitor	Exhibitors' titles, and descriptions	Time under trial
1	2	3	4	5	6
					h. m.
1	1	Dec. 17, 1881	J. G. Gray	Open grate, perforated loose back	5 0
2	4	„ 19 „	Barnard, Bishop & Barnards	The 'Anthracite grate'	6 0
3	4	„ 20 „	The British Sanitary Co.	Basket grate, enclosed in sheet-iron and glass; heating air	5 0
4	2	„ 26 „	M. Perret	'Radiating fire-grate,' firebrick lining and roof	4 0
5	2	„ 27 „	Do.	Do. do. do.	4 57
6	4	„ 28 „	J. Wright & Co.	'Hygienic ventilating stove,' reversed draft, air heated	5 0
7	2	„ 29 „	M. Perret	As before (No. 4)	6 0
8	2	„ 30 „	Do.	As before (No. 4)	4 37
9	5	„ 30 „	J. Wright & Co.	Hygienic stove, as above	6 0
10	3	Jan. 12, 1882	J. Potter & Sons	Open grate: thermhydric (hot-water pipes), air heated	9 30
11	3	„ 23 „	Perceval & Westmacott	'Parlour stove,' heating and cooking; air heated	5 0
12	In arcade	„ 25 „	James Smith	Open grate: coal coked at back	5 0
13	4	„ 25 „	W. Poore & Co.	'Triumph' stove: firebrick lining, and blower	5 0
14	4	„ 26 „	Do.	Do. do. do.	4 0
15	4	„ 27 „	T. Nash	Open grate: backdown draught to deposit soot	3 [illegible]
16	4	„ 28 „	Do.	Do. do. do.	5 [illegible]
17	2	„ 28 „	W. P. Taylor	Fresh-air opening in hearth; gilled and perforated back	5 [illegible]
18	2	Feb. 3 „	The Radiator Range Co.	Combustion chamber at back of grate	5 0
19	5	„ 4 „	A. B. Verrier	'Comet' grate: firebrick lining, blower, heating fresh air, and drawing foul air from upper part of room	5 [illegible]
20	5	„ 7 „	Do.	Do. do. do.	5 [illegible]
21	2	„ 7 „	Rosser & Russell	Fireclay back, fluted; air heated	5 [illegible]
22	2	„ 8 „	W. P. Taylor	Air opening in hearth, and openings through brick back	5 [illegible]
23	5	„ 9 „	G. Haller & Co.	Kohlhofer's hot-air stove: air-chamber above and at sides, up and down pipe-flues	5 [illegible]
24	4	„ 9 „	Perceval & Westmacott	'Sanitary stove'	5 [illegible]
25	3	„ 9 „	The Radiator Range Co.	As before (No. 18)	5 [illegible]
26	3	„ 15 „	E. H. Shorland	The 'Manchester' grate, G. L. Shorland's patent. Air heated, carried off in pipes	5 [illegible]
27	4	„ 21 „	A. C. Engert	The 'Solo' grate: half-barrel form grate	5 [illegible]
28	27 Cadogan Sq.	Mar. 16 „	R. H. Griffin	Perforated back, sides, and bottom. External air heated	6 [illegible]
29	1	„ 17 „	J. Wavish, plain grate	Plain grate	3 [illegible]
30	1	„ 18 „	Do. with apparatus	The 'Economiser:' air-cylinder in heart of fire	3 [illegible]
31	1	„ 20 „	Do. do.	Do. do.	[illegible]
32	1	„ 22 „	Do. plain grate	Plain grate	[illegible]

AND CLOSE STOVES FOR HEATING. 1881–82.

bottom grids and upward draught.

No. of test	Fuel-Consumed: Wood	Fuel-Consumed: Coal, Total, Description	Fuel-Consumed: Coal, Total, Weight	Fuel-Consumed: Coal, Per hour	Ash	Temperatures: External	Temperatures: At walls 6 feet high, At commencement	Temperatures: At walls 6 feet high, Total average	Temperatures: At walls 6 feet high, Average last hour	Temperatures: Difference due to radiation, 5 feet high, 6 feet from fire, Total average	Temperatures: Difference due to radiation, 5 feet high, 6 feet from fire, Average last hour	Chimney: Velocity of draught, Total average	Chimney: Velocity of draught, Average last hour	Chimney: Temperature, Total average	Chimney: Temperature, Average last hour	Smoke-Shade: Total average	Smoke-Shade: Average last hour
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	oz.		lb. oz.	lb. oz.	lb. oz.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	feet per minute	feet per minute	deg. F.	deg. F.	No.	No.
1	4	Wallsend	13 15	3 1¼	1 15	47·50	46·50	52·37	55·58	11·10	13·16	491·0	491	138·86	140·0	2·79	2·67
2	16	Wallsend Anthracite	3 0 9 8	2 1¼	2 0	39·0	43·25	53·44	57·91	9·69	18·67	330·8	328·33	222·0	240·0	1·92	1·00
3	16	Wallsend	15 0	3 0	0 12	42·19	44·25	53·68	58·25	6·55	10·67	331·90	360·0	—	—	4·71	3·67
4	40	Anthracite	8 0	2 0	1 6	44·0	43·50	48·60	51·0	15·63	19·67	316·31	330·0	259·09	346·67	0·79	0·33
5	32	Coke	31 8	6 3¾	2 12	44·0	48·50	61·39	62·25	23·25	24·0	456·66	430·0	194·55	180·0	0·0	0·0
6	16	Wallsend	31 11	6 5¼	4 1	41·0	45·0	54·82	63·05	12·59	18·67	405·27	430·0	311·67	371·67	3·89	2·0
7	32	Anthracite	24 8	4 1¾	3 14	45·69	45·25	56·45	57·25	22·50	28·0	356·92	330·0	214·61	163·33	0·57	0·0
8	16	Wallsend	32 15	7 2	1 8	45·0	48·75	62·95	69·08	32·70	43·33	613·33	630·0	327·78	400·0	3·55	4·33
9	16	Anthracite Wallsend	15 4 3 0	3 0⅔	1 8	45·0	45·0	50·44	54·08	7·84	10·0	346·80	393·3	174·70	220·0	1·60	0·67
10	32	Do.	35 8	3 12	1 8	46·0	54·50	73·85	81·25	24·25	27·0	430·0	—	—	—	3·50	—
11	24	Do.	12 0	2 6½	1 12	37·0	40·8	47·97	51·67	7·18	12·0	270·0	—	150·0	—	2·67	0·0
12	16	Coke Anthracite Wallsend-Slack	2 0¼ 2 0¼ 4 7½	1 11¼	—	29·0	—	—	—	11·37	20·67	291·40	303·30	208·0	213·30	1·67	0·67
13	24	Anthracite	13 8	2 11¼	3 14	31·0	41·0	44·83	48·42	5·67	10·33	—	—	120·0	—	0·0	0·0
14	22	Wallsend	17 13	4 7¾	1 5	32·0	41·0	51·67	58·25	17·56	25·33	—	—	195·0	210·0	4·11	2·6
15	16	Do.	10 11	3 9	0 4	47·0	51·0	60·70	66·90	12·30	20·0	390·71	410·0	191·43	220·0	4·83	3·33
16	17	Do.	15 8	3 1½	3 7	48·0	50·75	59·11	63·75	21·63	30·0	430·0	—	212·22	230·0	2·48	0·0
17	16	Do.	19 8	3 14¼	1 1	48·0	50·0	62·18	65·58	20·82	29·0	430·0	—	202·77	—	2·62	0·0
18	17	Do.	18 6	3 10¾	1 0	39·0	50·25	58·47	59·66	12·91	18·0	—	—	220·0	220·0	—	—
19	24	Do.	19 2	3 13¼	0 5	34·0	42·0	54·04	56·16	8·19	13·33	337·50	350·0	200·0	210·0	3·66	2·33
20	20	Do.	21 14	4 6	1 0	42·50	44·75	53·61	56·42	11·0	13·33	630·0	—	280·0	—	2·75	—
21	23	Do.	16 15	3 6¼	0 9	42·50	53·50	66·54	73·0	19·90	26·0	430·0	—	195·56	200·0	1·92	0·0
22	16	Do.	17 11	3 8½	0 6	40·0	49·0	59·09	64·25	26·91	36·0	630·0	—	214·0	260·0	3·50	2·0
23	24	Do.	30 12	6 2½	0 9	38·0	42·0	57·32	62·50	19·73	22·0	430·0	—	187·50	155·0	3·00	0·0
24	32	Do.	17 15	3 9½	0 6	38·0	47·30	68·87	73·58	10·72	11·33	165·0	195·0	206·67	—	5·58	4·67
25	24	Do.	24 12	4 15¼	2 4	38·0	46·25	60·48	62·17	21·36	24·34	480·0	—	187·0	200·0	—	—
26	32	Do.	32 13	6 9	0 12	40·0	50·50	64·68	68·25	14·54	19·0	315·0	—	150·0	—	2·87	1·00
27	32	Do.	20 0	4 0	1 1	50·0	50·75	58·14	61·67	12·18	16·0	492·0	—	221·11	—	1·81	3·00
28	32	Silkstone	29 0	4 13	1 0	54·0	54·0	62·0	65·0	—	—	—	—	—	—	0·75	0·0
29	16	Wallsend	17 1	3 11	0 6	58·0	50·0	58·50	59·83	16·0	17·50	—	—	—	—	2·53	1·00
30	16	Do.	16 10	3 5	—	61·0	48·0	58·0	60·50	17·0	19·84	—	—	—	—	1·31	1·33
31	16	Do.	15 8	—	—	58·0	49·67	61·0	62·67	13·0	19·33	—	—	—	—	1·42	0·33
32	16	Do.	18 10	—	1 0	45·50	45·0	52·0	53·0	20·0	21·34	—	—	—	—	2·25	0·50

Table III.—RESULTS OF TESTS OF OPEN GRATES AND

Class II. *Open Grates, having solid floors, adapted*

No. of test	No. of testing room	Date	Name of exhibitor	Exhibitors' titles, and descriptions	Time under trial
1	2	3	4	5	6
					h. m.
33	2	Dec. 16, 1881	Barnard, Bishop, & Barnards	'Glow-fire;' brick lumps	5 0
34	3	„ 19 „	Do. do.	'Bartlet' grate; brick lumps	6 0
35	2	„ 21 „	Do. do.	Do. do.	5 0
36	4	Jan. 5, 1882	The Derwent Foundry Co.	'Abbotsford' grate do.	5 0
37	5	„ 10 „	Marshall, Watson & Moorwood	'Harleston' grate; air heated behind	6 30
38	2	„ 14 „	Doulton & Co. . .	Fire-place of fire-brick slabs	5 30
39	4	„ 19 „	J. B. Petter . . .	'Nautilus' stove	5 20
40	5	„ 19 „	Steel & Garland . . .	'Wharncliffe' grate, air heated behind	5 30
41	5	„ 26 „	F. Edwards & Son . .	Dr. Arnott's grate	5 0
42	5	„ 27 „	Do. do. . . .	Downward-burning grate	5 0
43	5	„ 30 „	Do. do. . . .	Do. do.	5 0
44	2	„ 31 „	J. B. Petter	'Nautilus' stove	5 0
45	2	Feb. 10 „	Frost & Winfield . .	Fire lumps and baffle roofs	5 0
46	3	„ 14 „	Barnard, Bishop & Barnards	'Glow-fire'	5 0
47	2	Mar. 2 „	T. Mitchell . . .	Common grate, lined and floored with fireclay . . .	5 0
48	2	„ 3 „	Do. . . .	Do. in ordinary condition	5 0
49	2	„ 4 „	Do. . . .	Do. lined and open grid	5 0
50	2	„ 7 „	Do. . . .	Do. lined and floored with fireclay	5 0
51	2	„ 8 „	Do. . . .	Do. lined and open grid	5 0
52	2	„ 9 „	Do. . . .	Do. in ordinary condition	5 0

Class III. *Open Grates, underfed:—Supplied with fresh*

No. of test	No. of testing room	Date	Name of exhibitor	Exhibitors' titles, and descriptions	Time under trial
53	4	Dec. 27, 1881	E. R. Hollands . . .	Under-feeding, with movable grate	6 0
54	In Arcade	Jan. 25, 1882	H. Thompson . . .	Under-feeding, with movable plate floor	3 0
55	3	„ 25 „	Brown & Green . . .	Under-feeding, with tray in front	5 0
56	4	„ 31 „	W. S. Melville . . .	Under-feeding, shovel	5 0
57	5	Feb. 2 „	E. H. Shorland . . .	'Princess Louise,' G. L. Shorland's patent; under-feeding by shovel	5 0
58	3	„ 6 „	Yates, Haywood & Co. .	Under-feeding, with movable grate	5 0

CLOSE STOVES FOR HEATING. 1881-82—(*continued*).

for slow combustion and upward draught.

No. of test	Fuel Consumed: Wood	Fuel Consumed: Coal, Total: Description	Fuel Consumed: Coal, Total: Weight	Fuel Consumed: Coal, Per hour	Ash	Temperatures: External	Temperatures: At walls 6 feet high: At commencement	Temperatures: At walls 6 feet high: Total average	Temperatures: At walls 6 feet high: Average last hour	Difference due to radiation, 5 feet high, 6 feet from fire: Total average	Difference due to radiation, 5 feet high, 6 feet from fire: Average last hour	Chimney: Velocity of draught: Total average	Chimney: Velocity of draught: Average last hour	Chimney: Temperature: Total average	Chimney: Temperature: Average last hour	Smoke-Shade: Total average	Smoke-Shade: Average last hour
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	oz.		lb. oz.	lb. oz.	lb. oz.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	feet per minute	feet per minute	deg. F.	deg. F.	No.	No.
33	8	Wallsend	10 12	2 2½	4 3	46°0	50°50	56°84	59°04	14°09	10°17	303·0	303·0	172°86	175°0	3·77	1·67
34	16 {	Coke Wallsend	6 0 11 10	} 2 15	1 8	41·50	41·50	49·0	52·25	12·57	17·33	363·0	—	102·0	—	3·0	3·0
35	16 {	Wallsend Anthracite	12 8 4 4	} 3 5½	2 12	42·0	45·50	54·23	59·0	12·55	20·67	317·50	350·0	204·45	220·0	5·10	4·33
36	32	Wallsend	12 11	2 8¼	1 0	50·0	52·50	60·29	63·0	12·0	14·67	330·0	—	150·0	160·0	4·21	3·33
37	24	Do.	37 0	5 11	0 8	42·0	45·25	54·24	62·84	17·0	17·67	497·08	513·33	260 77	290·0	4·36	2·33
38	48	Do.	21 13	3 15½	0 14	42·0	51·75	66·71	72·83	12·75	15·0	291·0	—	144·0	140·0	1·33	0·0
39	16	Do.	12 0	2 4	—	38·0	49·75	58·15	64·0	9·16	15·33	226·11	324·33	230·0	240·0	3·89	1·67
40	32	Do.	20 0	3 10¼	—	38·0	45·0	52·85	59·85	21·77	27·0	418·0	480·0	257·27	363·33	3·86	1·67
41	19	Do.	17 13	3 9	1 14	32·0	36·50	44·14	44·17	11·46	14·67	430·0	430·0	155·0	185·0	3·10	1·33
42	18	Do.	19 3	3 13½	2 5	42·0	41·50	49·43	50·50	14·18	18·30	430·0	—	170·0	183·33	2·28	0·0
43	18	Do.	20 10	4 2	3 7	43·0	43·75	47·75	50·09	15·28	20·0	630·0	—	192·50	200·0	3·00	0·0
44	9	Do.	13 9	2 11½	2 3	40·0	47·50	58·83	63·58	13·91	17·70	180·0	—	210·0	240·0	2·81	0·33
45	32	Do.	17 12	3 8¾	0 12	38·0	51·50	57·06	59·16	15·09	17·34	270·0	—	190·0	—	4·43	1·0
46	16	Do.	10 5	2 1	0 3	53·27	53·25	61·43	61·74	13·26	19·0	305·0	—	102·50	140·0	2·36	0·0
47	16	Do.	13 1	2 9¾	0 9	42·0	46·0	55·0	60·09	19·0	25·0	—	—	—	—	3·60	3·0
48	16	Do.	18 3	3 10¼	0 3½	42·0	46·0	55·05	60·08	18·82	24·67	—	—	—	—	2·78	0·67
49	16	Do.	15 5	3 1	0 2	36·0	43·0	50·12	54·42	11·64	17·66	—	—	—	—	3·40	2·33
50	16	Do.	13 8	2 11¾	0 8	50·0	49 0	54·70	58·09	11·55	14·0	—	—	—	—	3·40	1·33
51	16	Do.	15 14	3 2¾	0 14	53·0	52·25	58·0	61·42	13·0	17 0	—	—	—	—	2·40	0·33
52	16	Do.	20 4	4 0¾	0 8	54·0	53·75	63·0	67·33	18·50	24·0	—	—	—	—	1·55	0·0

uel beneath the incandescent fuel, with upward draught.

No. of test	Wood	Description	Weight	Per hour	Ash	External	At commencement	Total average	Average last hour	Total average	Average last hour	Total average	Average last hour	Total average	Average last hour	Total average	Average last hour
53	11 {	Wallsend Cinders	15 0 0 11	} 2 9¾	1 0	43·52	45 25	57·84	64·50	13·20	15·0	370·0	430·0	134·80	210·0	2·52	1·0
54	16 {	Wallsend Cinders	2 5¼ 0 14¾	} 1 1¾	0 4	—	—	—	—	10·30	—	—	—	--	—	3·00	2·33
55	21	Wallsend	20 3	4 0¼	2 1	31·0	41·50	53·02	56·83	21·46	27·30	430·0	—	137·50	155·0	2·12	—
56	24	Do.	11 5	2 4¼	0 9	40·0	50·25	61·20	62·80	9·10	11 0	193·33	210·0	202·0	120·0	4·14	3·0
57	16	Do.	12 3	2 7	1 2	33·0	39·50	47·15	50·22	15·0	19·30	430·0	—	259·0	290·0	3·00	2·0
58	24	Do.	16 4	3 4	1 7	40·0	48·75	54·13	56·67	9·18	13·33	330·0	—	206·2	225·0	2·31	3·33

TABLE III.—RESULTS OF TESTS OF OPEN GRATES AND

CLASS IV. *Open Grates to which fresh fuel is supplied*

No. of test	No. of testing room	Date	Name of exhibitor	Exhibitors' titles, and descriptions	Time under trial
1	2	3	4	5	6
					h. m.
59	1	Dec. 12, 1881	A. C. Engert . . .	Coking box at back	5 34
60	4	Feb. 20, 1882	Do.	Do. do.	5 0
			HOPPER-FED.		
61	4	Dec. 15, 1881	Musgrave & Co. . . .	'Ulster' register stove, hopper at back, heats air . . .	5 0
62	3	„ 20 „	The Coalbrookdale Company	'Gassius' grate, hopper fed, solid bottom	5 0
63	4	„ 31 „	J. M. Stanley . . .	Downward draft, hopper fed	6 0
64	4	Jan. 2, 1882	Do. . .	Do. do.	6 0
65	4	Feb. 2 „	H. E. Hoole . . .	Hopper at each side, openings at bottom; conical reflector .	5 0
66	4	„ 3 „	Archibald Smith & Stevens	'Wonderful' grate, hopper at back	5 0
67	4	„ 4 „	Do. do.	Do. do. do.	5 0

CLASS V. *Open Grates, having a downward,*

68	4	Dec. 24, 1881	The Coalbrookdale Co. .	'Kyrle' grate, firebrick lining and floor, backward draught at bottom	5 0
69	3	„ 24 „	Captain T. E. Clarke . .	Downward draught, air heated behind	5 0
70	3	„ 27 „	Do. do. . .	Do. do. do.	5 0
71	4	Jan. 4, 1882	The Derwent Foundry Co.	'Smoke-burning register,' Jobson's patent; downward and backward draught; tubular air-bars	6 0
72	3	„ 4 „	M. Feetham & Co. . .	Ventilating dog grate, fire-basket, downward draught . .	4 32
73	3	„ 7 „	Do. do. . .	'Hurst' grate, downward and backward draught, air heated.	6 0
74	3	„ 9 „	Do. do. . .	Do. do. do. .	5 30
75	3	„ 10 „	Do. do. . .	Do. do. do. .	6 0
76	4	„ 12 „	Yates, Haywood & Co. .	Redmayne's patent, backward draught, solid floor, air heated	5 30
77	4	„ 13 „	Do. do. . .	Do. do. do.	5 30
78	3	„ 16 „	Deane & Co. . . .	Crane's anthracite grate, firebrick back and sides, downward draught	5 0
79	3	„ 17 „	Do. . . .	Do. do. do.	5 0
80	4	„ 18 „	J. Moore	Draught backwards and downwards, air heating . . .	5 0
81	2	„ 21 „	Steel & Garland . . .	'Kensington' grate, back and side draughts into flue, air heating	5 30
82	4	„ 21 „	Clark, Bunnett & Co. . .	Ingram's 'Kaio-Kapnos' grate: backward draught, air heating	5 0
83	4	„ 23 „	Do. do. . .	Do. do. do. .	5 0
84	2	„ 23 „	Steel & Garland . . .	'Kensington' grate, as above	5 0
85	3	„ 24 „	Brown & Green . . .	'Luton' register grate, backward draught	5 0
86	3	Feb. 1 „	W. I. Henry . . .	Reeve & Henry's 'smoke purifyer' ('Calpean'), hob grate, backward draught, and filter chamber	5 0
87	3	„ 2 „	Do. . . .	Do. do. do.	5 0
88	2	„ 2 „	T. E. Parker . . .	Downward and backward draught	5 0
89	3	„ 4 „	Do. . . .	Do. do.	5 0
90	3	„ 7 „	J. Cornforth . . .	Hollow air-bars and backward draught	5 0
91	4	„ 8 „	W. I. Henry . . .	Reeve and Henry's 'smoke purifyer' ('Calpean'), register grate, with back draught and filter chamber . . .	5 0
92	4	„ 10 „	Deane & Co. . . .	Crane's grate, as above	5 0
93	2	„ 25 „	W. Lawrence . . .	Backward draught, into a combustion chamber . . .	5 0
94	4	Mar. 15 „	The Wilson Engineering Co.	Backward and lateral draught	5 0

OSE STOVES FOR HEATING. 1881-82—*(continued).*

om the back, or from the sides, or from hoppers.

Fuel Consumed					Temperatures						Chimney				Smoke-Shade	
Wood	Coal: Total: Description	Coal: Total: Weight	Coal: Per hour	Ash	External	At walls 6 feet high: At commencement	At walls 6 feet high: Total average	At walls 6 feet high: Average last hour	Difference due to radiation, 5 feet high, 6ft. from fire: Total average	Difference due to radiation: Average last hour	Velocity of draught: Total average	Velocity of draught: Average last hour	Temperature: Total average	Temperature: Average last hour	Total average	Average last hour
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
oz.		lb. oz.	lb. oz.	lb. oz.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	feet per minute	feet per minute	deg. F.	deg. F.	No.	No.
12	Lambton Hard Stm. Wallsend	13 12 14 0 4 6	5 12¾	0 13	38·50	39·0	57·33	61·81	7·92	8·67	—	—	—	—	1·66	0·0
32	Wallsend	14 3	2 13½	0 4	39·0	49·0	56·52	57·16	11·28	13·0	337·0	—	160·0	—	2·92	0·33
16	Cinders Wallsend	4 8 12 0	3 5	0 14	43·0	49·0	56·15	58·08	10·30	11·66	345·0	—	—	—	2·22	1·67
24	Wallsend	17 8	3 8	2 6	42·0	45·50	53·79	57·75	8·55	14·0	459·0	—	118·0	145·0	1·76	0·0
16	Do.	32 8	5 6¾	1 0	45·0	54·50	68·92	77·66	10·0	15·0	348·0	333·33	323·0	400·0	2·24	2·0
32	Wallsend Anthracite	3 0 21 0	4 0	1 0	48·0	49·75	61·78	70·58	9·01	12·67	328·80	296·67	213·77	266·77	0·88	0·0
24	Wallsend	10 14	2 2¾	0 4	33·0	45·0	58·80	63·20	14·60	23·0	180·0	—	157·78	186·67	2·55	1·33
32	Anthracite	19 11	3 15¾	0 8	39·0	53·0	60·91	64·50	14·46	22·0	452·0	563·33	251·0	276·67	0·52	0·0
24	Wallsend	25 4	5 0¾	0 14	34·0	46·0	57·02	61·16	14·09	20·67	401·11	423·33	256·67	286·67	4·29	4·33

backward, or a lateral draught.

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
32	Anthracite	8 8	1 11¼	2 0	35·0	43·0	51·11	54·25	13·11	18·34	316·0	—	—	—	0·00	0·0
12	Wallsend	12 13	2 9	0 8½	35·0	41·0	50·0	55·91	7·90	11·33	270·0	—	—	—	1·75	0·67
16	Do.	11 12	2 5¼	1 8	44·0	47·2	52·29	55·58	8·73	11·33	330·0	—	—	—	2·93	1·0
32	Do.	31 8	5 4	1 0	40·0	53·0	64·25	68·83	17·08	14·33	350·0	420·30	249·90	290·0	3·16	1·33
32	Do.	21 15	4 13½	0 4	38·0	56·50	69·22	76·17	23·21	29·0	530·0	—	182·0	—	1·19	0·0
16	Do.	19 8	3 4	1 0	42·0	53·2	66·60	71·50	27·30	41·0	270·0	—	295·0	—	1·41	0·0
32	Anthracite	12 0	2 3	3 5	42·0	49·5	61·14	64·83	14·0	22·0	270·0	270·0	160·0	—	1·33	0·0
32	Wallsend	19 4	3 3¼	1 0	42·0	46·8	60·30	67·0	19·23	16·67	270·0	—	162·27	—	—	—
24	Do.	25 0	4 8¾	—	47·0	54·0	68·94	76·17	15·77	22·33	246·10	203·33	216·67	240·0	4·73	3·67
32	Anthracite	20 4	3 11	—	47·0	52·8	71·39	75·83	15·35	21·66	289·05	363·33	195·45	246·67	0·27	0·0
23	Do.	16 0	3 3¼	1 13	44·0	50·8	60·74	63·08	15·91	26·34	302·0	—	200·0	240·0	0·18	0·0
24	Wallsend	15 4	3 0¾	1 4	34·0	47·8	59·95	64·33	19·19	25·67	383·0	—	225·0	220·0	3·90	3·33
22	Do.	16 5	3 4¼	0 3	33·0	43·8	56·90	70·42	12·09	15·33	330·0	—	190·0	—	2·50	3·0
32	Do.	19 13	3 9¼	1 5	36·50	44·2	60·66	67·41	15·16	23·33	—	—	—	—	3·66	1·0
24	Do.	28 8	5 11¼	—	36·0	45·0	56·65	59·66	18·28	22·0	520·0	550·00	350·0	350·0	3·31	2·67
32	Anthracite	24 15	4 15¾	5 0	37·0	44·8	53·36	57·50	13·0	23·0	330·0	—	200·0	—	0·00	0·0
32	Do.	31 1	6 3¼	6 0	37·0	47·0	55·22	61·75	7·80	15·0	430·0	—	130·0	—	0·00	0·0
28	Do.	13 0	2 9½	3 14	36·0	45·5	54·79	58·25	12·55	16·0	430·0	430·0	127·50	140·0	0·00	0·0
9	Wallsend	6 15	1 6¼	0 8	36·0	50·5	58·07	61·17	3·27	3·66	230·0	—	110·0	120·0	1·62	0·33
14	Do.	10 5	2 1	0 10	33·0	42·5	47·43	51·34	8·82	11·0	430·0	—	116·11	125·0	1·83	0·0
14	Do.	17 4	3 7¼	0 3	33·0	43·0	61·72	69·08	11·36	15·0	270·0	—	180·0	—	2·20	0·33
16	Do.	15 10	3 2	0 3	34·0	42·8	57·47	58·50	12·09	16·0	330·0	—	156·70	180·0	2·37	—
20	Do.	24 3	4 13½	1 6	42·50	49·0	63·50	68·0	16·73	22·33	430·0	—	260·0	—	3·50	—
10	Do.	6 5	1 4¼	0 4	40·0	50·0	54·02	56·92	5·27	8·33	210·0	—	95·0	110·0	0·91	0·33
20	Do.	14 12	2 15¼	0 15	38·0	45·5	52·05	55·08	12·11	15·33	252·0	252·0	160·0	160·0	4·45	0·10
24	Do.	35 8	7 1½	0 11	50·50	50·8	62·07	67·25	20·09	19·67	596·0	—	376·20	—	2·72	0·33
16	Hard Stm. Wallsend	18 8 1 14	4 1¼	1 2	49·0	48·3	56·09	60·17	12·73	16·00	325·0	330·0	—	—	1·23	1·33

TABLE III.—RESULTS OF TESTS OF OPEN GRATES AND

CLASS VI.

No. of test	No. of testing room	Date	Name of exhibitor	Exhibitors' titles, and descriptions	Time under trial
1	2	3	4	5	6
					h. m.
95	5	Dec. 15, 1881	C. B. Gregory . . .	'Smoke-burning furnace'	3 0
96	3	„ 15–16 „	Musgrave & Co. . . .	Slow-combustion stove	24 0
97	2	„ 23 „	Rev. H. J. Newcome . .	'Tubular air warmer'	4 0
98	5	„ 23–24 „	B. J. Klingenberg . .	Reck's heating and ventilating stove	27 35
99	3	„ 30–31 „	C. Portway & Son . .	'Tortoise' stove, slow combustion heating and laundry stove	24 0
100	5	Jan. 4, 1882	The Derwent Foundry Co.	Jobson's 'Slow combustion gill stove,' downward draught .	6 0
101	2	„ 6 „	Doulton & Co. . . .	'Spiral' stove of stoneware, air heating	9 30
102	4	„ 7 „	H. Hunt	'Economy' portable heating stove.	6 0
103	5	„ 7 „	Do.	'Economy' base burner	6 0
104	4	„ 10 „	Yates, Haywood & Co.	'Miser' stove, two pillars	5 0
105	2	„ 11 „	J. Cornforth . . .	'Little Wonder' stove: hollow fire-bars to burn the gases .	5 0
106	5	„ 12 „	R. W. Crosthwaite . .	Armstead's stove No. 3, delivering hot air	5 30
107	2	„ 12 „	Do. .	Do. 1 Do.	5 40
108	2	„ 13 „	Do. .	Do. 2 Do.	6 0
109	5	„ 13 „	Do. .	Do. 4 Do.	5 30
110	5	„ 14 „	Do. .	Do. 5 Do.	5 30
111	5	„ 18 „	W. Stobbs	'Crystal' ventilating grate	5 0
112	2	„ 19 „	Doulton & Co. . . .	'Top-feeding' stove, stoneware, air heating	9 0
113	5	„ 21 „	H. Hunt	'Crown Jewel' base burner hall stove	5 0
114	5	„ 24 „	Do.	'Hygiene' ventilating stove, base burner; heated air . .	5 0
115	4	„ 24 „	Van der Harst . . .	Charcoal stove	5 0
116	2	„ 24 „	Steel & Garland. . .	4-Pillar stove ('Miser' class).	5 0
117	3	„ 27 „	Brown & Green . . .	'Twin' stove	5 0
118	3	„ 30 „	J. F. Farwig & Co. .	'Calorigen' stove, air heating	5 0
119	3	„ 31 „	The Sunlight Stove Co. .	'Sunlight' stove	5 0
120	5	„ 31 „	J. Dunnachie . . .	'Star' heating-stove, firebrick	5 0
121	2	Feb. 1 „	Doulton & Co. . . .	Ordinary large stove, stoneware, with baffler	10 0
122	5	„ 6 „	W. Barton	'The Premier' stove	5 0
123	5	„ 8 „	F. Lönholdt . . .	Anthracite stove, air heating	5 0
124	5	„ 10–11 „	Do. . . .	Do. do.	23 30
125	5	„ 11 „	Do. . . .	Do. do.	3 0
126	5	„ 13 „	H. J. Piron . . .	Hot-air stove and ventilator	5 0
127	5	„ 14 „	R. W. Crosthwaite . .	Armstead-Gregory stove.	4 30
128	2	„ 27 „	Brown & Green . . .	'Albion' stove	5 0
129	3	Mar. 1 „	Do . . .	Close stove, with reversible draught	5 0
130	2	May 18 „	J. Dunnachie . . .	'Star' heating-stove, as above	5 8

CLOSE STOVES FOR HEATING. 1881–82—(*continued*).

Close Stoves.

No. of test	Fuel Consumed: Wood	Fuel Consumed: Coal, Total: Description	Coal, Total: Weight (lb.)	Coal, Total: Weight (oz.)	Coal, Per hour (lb.)	Coal, Per hour (oz.)	Ash (lb.)	Ash (oz.)	Temperatures: External	At walls 6 feet high: At commencement	At walls 6 feet high: Total average	At walls 6 feet high: Average last hour	Difference due to radiation, 5 feet high, 6 feet from fire: Total average	Difference: Average last hour	Chimney: Velocity of draught: Total average	Velocity of draught: Average last hour	Chimney: Temperature: Total average	Temperature: Average last hour	Smoke-Shade: Total average	Smoke-Shade: Average last hour
	7	8	9		10		11		12	13	14	15	16	17	18	19	20	21	22	23
	oz.		lb.	oz.	lb.	oz.	lb.	oz.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	feet per minute	feet per minute	deg. F.	deg. F.	No.	No.
95	Wood 25½ lbs.; Sawdust 6¼ lbs.; Shaving 2 oz.	Walls-end	63	0	21	0	—		42·0	45	79·68	91·25	13·86	16·0	666·0	666·0	—	—	0·00	0·00
96	21	Coke	53	8	2	3½	5	4	43·0	62·2	15th, 77·86	82·7	9·85	12·67	117·0	—	400·0	—	0·00	0·00
											16th, 65·04	—	5·00	—	—	—	160·0	—	0·00	0·00
97	10	Wallsend	13	12	3	7	0	4	42·0	42·0	58·60	65·25	3·60	5·00	173·0	—	90·0	—	2·00	0·00
98	16	,,	63	4	2	5	6	4	33·9	41·0	23rd, 48·20	52·50	2·00	1·67	—	—	—	—	1·75	—
											24th, 49·50	49·50	1·66	1·66	—	—	—	—	0·00	—
99	16	Coke	18	8	2	0½	2	0	45·0	49·5	30th, 67·16	76·41	12·91	18·0	164·0	—	137·0	—	0·00	0·00
											31st, 61·33	—	4·0	—	—	—	—	—	—	—
100	32	Wallsend	21	8	3	9¼	1	0	40·0	42·2	47·40	50·50	1·31	1·0	263·48	273·0	158·0	200·0	2·35	0·00
101	16	Hard stm.	10	2½	1	1	0	3½	53·0	56·0	67·09	74·42	2·10	2·33	—	—	65·0	—	1·04	0·00
102	24	Anthracite	15	0	2	8	0	12	42·0	46·5	66·77	72·33	6·91	9·67	263·20	300·0	152·31	180·0	0·30	0·00
103	32	,,	15	4	2	8⅞	0	5	42·0	45·8	51·44	54·84	3·31	4·0	212·92	183·33	165·83	180·0	—	0·00
104	16	Wallsend	9	4	1	13½	0	8	42·0	48·0	60·56	65·08	4·25	5·67	121·0	—	—	—	4·48	3·00
105	20	,,	18	12	3	12	1	12	50·0	54·5	88·41	96·66	15·36	18·0	430·0	—	180·50	185·0	0·69	0·00
106	32	Anthracite	27	0	4	14½	1	8	47·0	50·0	60·56	70·83	7·42	13·67	232·73	270·0	190·0	203·33	0·50	0·33
107	24	,,	11	10	2	0¾	6	8	46·0	58·8	69·90	77·33	7·82	10·0	—	—	—	—	0·00	0·00
108	24	,,	17	14	2	15	3	11	47·0	55·5	68·51	72·0	8·54	10·0	180·0	—	—	220·0	0·00	0·00
109	32	,,	33	0	6	0	1	6	47·0	52·8	69·87	75·50	17·75	17·56	320·0	350·0	239·09	350·0	0·00	0·00
110	32	,,	58	12	10	11	1	8	42·0	52·0	67·83	77·41	17·17	23·0	295·45	330·0	231·82	250·0	0·00	0·00
111	12	,,	10	3	2	0½	2	0	33·0	47·5	62·84	69·50	10·91	15·67	163·33	—	222·50	246·67	0·75	0·00
112	32	Hard stm.	26	0	2	14¼	0	13	38·0	44·0	62·09	74·83	13·47	5·0	80·0	—	167·0	—	—	—
113	32	Anthracite	12	0	2	6¼	0	12	36·0	41·2	51·90	58·40	6·58	9·70	177·89	213·33	181·43	180·0	0·0	0·00
114	32	,,	28	14	5	12½	1	2	36·0	39·3	58·60	70·80	16·40	20·30	211·0	223·33	195·0	230·0	0·0	0·00
115	—	Charcoal Briquettes	3	7	0	11	0	12¼	37·0	42·0	52·70	57·60	0·40	—	—	—	—	—	—	—
116	32	Wallsend	11	14½	2	6	1	5	36·0	44·0	56·93	66·33	8·91	15·0	—	—	145·0	—	2·36	0·00
117	32	Hucknall	18	15	3	12½	2	13	42·0	49·5	64·11	67·50	8·63	11·0	—	—	129·50	140·0	3·06	0·00
118	32	Wallsend	13	15	2	12½	2	9	43·0	54·5	62·20	65·75	6·18	11·33	—	—	207·0	250·0	1·16	0·00
119	32	,,	38	14	7	12¼	1	6	40·0	48·0	70·99	82·33	20·09	24·70	230·0	—	297·0	350·0	6·31	4·33
120	24	,,	25	3	5	0¼	4	0	40·0	45·0	53·50	55·50	12·20	17·70	560·0	600·0	342·0	320·0	2·48	2·33
121	32	Hard stm.	22	9	2	4	0	13	36·0	46·0	59·08	69·08	5·38	7·33	—	—	—	—	0·80	0·00
122	32	Coke	18	6	3	10¾	1	2	40·0	46·5	55·95	60·0	7·73	9·33	—	—	126·0	140·0	0·0	0·00
123	28	Anthracite	6	8	1	4⅞	0	5	40·0	43·5	53·48	57·75	4·81	3·0	181·25	181·67	83·25	84·33	1·50	1·50
124	29	,,	26	0	1	1⅞	0	4	38·0	41·0	10th, 53·16	58·75	11·18	12·67	75·57	94·33	66·89	64·0	0·18	0·00
											11th, 48·67	—	9·0	—	—	—	58·0	—	—	0·00
125	8	,,	11	5	3	12¼	—		50·0	50·8	62·65	66·62	6·0	17·83	151·67	155·0	183·0	—	0·0	0·00
126	32	,,	33	2	6	10	2	4	48·0	48·0	62·64	63·58	7·64	7·0	331·0	—	248·0	200·0	0·0	0·00
127	96	Wallsend	32	3	7	2	1	1	54·0	52·2	70·15	78·25	17·10	21·66	455·0	455·0	196·25	190·0	0·46	0·00
128	24	Anthracite	19	3	3	13⅓	0	2	51·0	52·0	68·0	77·50	12·73	18·0	—	—	105·0	120·0	0·0	0·00
129	24	Hucknall	24	12	4	15¼	0	12	48·0	51·2	65·43	71·50	10·49	19·0	368·0	—	150·0	—	2·38	0·00
130	16	Wallsend	9	15	1	12⅞	0	5	58½	55	63·27	67·70	1·42	—	—	—	101·0	96·0	1·33	0·00

INVESTIGATION OF THE RESULTS OF THE TESTS.

PREVENTION OF SMOKE.

When it is considered that the primary conditions for the complete combustion of fuel and the prevention of smoke are, that the combustible gases should be intimately mixed with air, and that the mixture should be effected and maintained at a high temperature, it may be expected that such grates and stoves as present the most favourable disposition in fulfilment of these conditions should be the most effective for the prevention of smoke. The averaged smoke-shades of the several classes of grates and of close stoves burning Wallsend coal are here arranged in the order of the intensity of smoke-shade.

Class 2	. . . .	3·23	average	smoke-shade
,, 1	. . . .	3·01	,,	,,
,, 3	. . . .	2·82	,,	,,
,, 5	. . . .	2·73	,,	,,
,, 4	. . . .	2·66	,,	,,
,, 6	. . . .	2·11	,,	,,

Here, it appears that Classes 1 and 2, taken together, are the least effective for the prevention of smoke. These are the grates which have direct upward draught; and of these two Classes, it appears that the grates of Class 2, having solid floors, are less effective than those of Class 1, which have an open grid for the admission of air below. The close stoves of Class 6 are clearly more effective than any class of open grates, for prevention of smoke. In these stoves, the supply of air for combustion is strictly regulated, and is forcibly mixed with the hot gases. The effectiveness of such conditions is strikingly rendered by Mr. Crosthwaite, in the Armstead stove fitted with Gregory's feeder. The intermediate classes appear to be intermediately effective; and evidently, of these, Class 4 is the most effective, where the fresh fuel is very gradually distilled, and the smoke-making gases very gradually consumed. In the two other intermediate classes, 3 and 5, the gases from the fresh fuel are drawn upwards or downwards through the incandescent fuel; and though no doubt they are raised to and maintained at a temperature sufficient for combustion, the supply of air is not sufficiently intermixed with the gases to complete the combustion.

These deductions are confirmed by the results of the chemical tests of the gases of combustion in the chimney, conducted by Professor W. Chandler Roberts, F.R.S.

TEMPERATURE OF THE ROOM.

Equal in importance to the prevention of smoke, is the degree of elevation of temperature in the room, effected by the combustion of fuel in grates and stoves. The following comparative statement (Table IV.) exhibits, in the seventh column, the average rise of temperature effected per pound of Wallsend coal consumed per hour, which is a measure of the comparative efficiency of the classes of grates and of stoves. The temperature at the six-feet level is taken as the standard rise of temperature in the room. In the sixth column, is the excess of the average temperature maintained during the test above the initial temperature of the room—the temperature at the commencement of the test. This is preferable, as a datum, to the external temperature given in the third column; for it is obvious, on a cursory inspection of Table II., that the external

temperature exercises much less influence in determining the temperature that is maintained in the room, than the initial temperature within the room, which is a measure of the heat lodged in the walls, floor, and ceiling. In the averages for Class 6, the exceptional instances, Nos. 96, 98, 99, and 124, have not been included, and in the alternative line of averages given for Class 6, the specially large and important stove of Mr. Gregory, No. 95, is not included. In calculating the average equivalent rise of temperatures, column 6, the observed average elevations of temperature in the case of tests conducted in room No. 5, which was twice as capacious as the smaller rooms, were augmented by one-half of their values respectively to supply the equivalent elevation of temperature that would have been attained supposing that the test had been conducted in one of the smaller rooms. The results of tests in No. 5 room are thus placed, for direct comparison, on the footing of tests conducted in the smaller rooms. The rise of temperature per pound of coal consumed per hour, column 7, is the direct average of the several quotients calculated for each test for each class.

Table IV.—Rise of Temperature in the Room.

Class	Average weight of coal consumed per hour (Wallsend)	Average external temperature	Average initial temperature in the room	Average temperature actually maintained at a height of 6 feet	Average equivalent rise of temperature	
					Total	Per lb. of coal per hour
1	2	3	4	5	6	7
	lbs.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
No. 1	4·32	42·3	47·2	58·3	11·67	2·88
2	3·37	41·9	47 1	55·0	9·64	2·99
3	2·91	37·5	45·0	54·7	10·39	3·81
4	3 72	39·3	48·2	58·5	10·37	3·05
5	4·04	39·2	48·3	60·4	12·10	3·38
Averages Nos. 1 to 5 . . .	3·65	40·0	47·2	57·4	10·83	3·22
No. 6	5·79	45·3	49·2	67·9	21·55	4·14
„ 6 (not including C. B. Gregory's stove) . .	3·87	45·7	49·8	66·4	17·74	4.48

Place the classes in order of the heating efficiency, as represented in column 7 of the table, as follows, beginning with the class of lowest efficiency:—

Class 1	2·88 degrees F. rise of temperature per lb. of coal			
„ 2	2·99	„	„	„
„ 4	3·05	„	„	„
„ 5	3·38	„	„	„
„ 3	3·81	„	„	„
„ 6	4·48	„	„	„

From this statement, it appears that ordinary open-burning fires, having bottom grids (Class 1) or solid floors (Class 2), are the least effective for warming the room relatively to the quantity of coal consumed per hour. Next in order are open fires feeding at the sides or the back, or from hoppers (Class 4). Then come the grates of Class 5, having a downward or a horizontal draught, and lastly, as the most efficient of the open grates, those which are under-fed, with an upward through draught (Class 3)—one-third better than those of Class 1.

It may be inferred that open grates (Classes 3 and 5) constructed on the principle of drawing the combustible gases through the incandescent fuel, are the most efficient; and that, of these, the best are those (Class 3) which supply the fresh fuel below the fire, and cause the combustible gases to rise upwards through it.

The close stoves (Class 6) are clearly more efficient per pound of coal for raising the temperature of the room than the open grates: being one-third better than the average of these, and one-sixth better than the best of these.

The under-fed open grates (Class 3) are the only grates which are capable of continuously exposing a bright and open surface, unchecked by the presence of fresh coal, as well as of smoke, and unobstructed by special appliances; and it is probable that the apparent excellence of the grates of Class 3 amongst other open grates is very much attributable to their distinctive characteristic.

A general correspondence may be observed between the smoke-shades, page 70, and the efficiencies, as marked by the rise of temperature in column 7 of the foregoing table: the efficiencies increasing as the smoke-shades are reduced. They are here placed in parallel columns for comparison: the order for smoke-shades being followed.

TABLE V.—SMOKE-SHADES AND TEMPERATURES—WALLSEND COAL.

Class	Average smoke-shade	Average rise of temperature per lb. of coal per hour
		deg. F.
2	3·23	2·99
1	3·01	2·88
3	2·82	3·81
5	2·73	3·38
4	2·66	3·05
6	2·11	4·48

Here the efficiency increases generally as the smoke-shade is diminished. If Classes 3 and 4, which comprise very few tests, be omitted for the moment, the remaining classes, 2 and 1 (taken together), 5, and 6, will range in due order, for rise of temperature, so that the efficiency of the most numerously represented classes varies inversely with the smoke-shade: that is to say, inversely with the imperfectness of combustion as expressed by smoke-shade.

RADIATING POWER.

The differences of temperature indicated on thermometers facing the fire, and others back to back with these, afford a measure of the power of radiating heat. The single vertical line of thermometers employed for the tests, although to some extent useful, was certainly not exhaustive; and did not suffice to indicate proportionally the whole of the heat that was radiated from the fire. Besides the heat radiated directly in front of the fire, much heat was in many instances radiated obliquely into the room, from the flanks of the fire-place, which did not necessarily bear any general relation to the front radiation.

The force of radiation, as observed, is, therefore, not to be taken as a measure of the whole quantity of heat that was radiated into the room. Nevertheless, a few useful deductions may be based upon the results of the observations, which are summarised for the tests made with Wallsend coal in the following table. The results of observations for radiation taken at the three different levels already stated, page 46, have been averaged for each test, and the averages of these are placed in the table. The averages, for three different levels, it may be noted, are distinguished from those given in the large tables, inasmuch as these are given only for one level, at five feet above the floor.

It appears that the total average radiations from the several classes of open grates (column 5) vary generally in correspondence with the total average elevation of tempera-

ture (column 3). So also do the radiations and temperatures per pound of coal consumed per hour, though there are irregularities which are due to the varying circumstances of fire-places. But there is clearly a greater degree of radiation from the open grates, taken together, than from the close stoves: unobstructed front radiation from the grates in contrast with diffused radiation of heat transmitted through close stoves. From

TABLE VI.—RADIATION OF HEAT FROM GRATES AND STOVES—WALLSEND COAL.

Class 1	Average weight of coal consumed per hour (Wallsend) 2	Average equivalent rise of temperature		Average measure of radiation	
		Total 3	Per lb. of coal per hour 4	Total 5	Per lb. of coal per hour 6
No.	lbs.	deg. F.	deg. F.	deg. F.	deg. F.
1	4·32	11·67	2·88	13·62	3·58
2	3·37	9·64	2·90	12·92	4·07
3	2·91	10·39	3·81	10·40	3·61
4	3·72	10·37	3·05	10·64	3·14
5	4·04	12·10	3·38	13·90	3·70
Averages Nos. 1 to 5 . . .	3·65	10·83	3·22	12·47	3·62
No. 6 . . .	5·79	21·56	4·14	7·97	1·66
„ 6 (not including C. B. Gregory) . .	3·87	17·74	4·48	7·54	1·79

these, standing clear of the walls, heat was radiated in every direction. The contrast in this respect is the more notable as the rise of temperature was decidedly greater with the close stoves than with the open grates.

The relation between the smoke-shades and the observed radiations of heat may be gathered from the following parallel columns:—

TABLE VII.—SMOKE-SHADES AND RADIATIONS—WALLSEND COAL.

Class	Average smoke-shade	Average measure of radiation per lb. of coal
		deg. F.
2	3·23	4·07
1	3·01	3·58
3	2·82	3·61
5	2·73	3·70
4	2·66	3·14
6	2·11	1·79

GRATES AND STOVES BURNING ANTHRACITE.

Open grates in Classes 1, 4, and 5, burning anthracite, were tested; also close stoves, Class 6. The results of 27 tests of grates and stoves in raising the temperature of the rooms, and in radiation, are given in Table VIII. The averages per pound of fuel, in columns 3 and 5, have been struck directly from the quotients derived for the several tests.

TABLE VIII.—RISE OF TEMPERATURE AND RADIATION OF HEAT, WITH ANTHRACITE.

Class	Average weight of anthracite consumed per hour	Average equivalent rise of temperature		Average measure of radiation	
		Total	Per lb. of coal per hour	Total	Per lb. of coal per hour
1	2	3	4	5	6
No.	lbs.	deg. F.	deg. F.	deg. F.	deg. F.
1	2·93	7·58	2·97	8·58	2·64
4	4·00	9·97	2·50	10·83	2·71
5	3·52	10·19	3·27	12·46	4·22
Averages Nos. 1, 4, 5 . . .	3·48	8·97	2·91	10·62	3·19
No. 6 . . .	4·12	18·38	5·61	7·95	2·37

Of the three classes of open grates, and the close stoves, tested with anthracite, the efficiency in raising the temperature is here brought into comparison with the same classes tested with Wallsend coal:—

TABLE IX.—ANTHRACITE *versus* WALLSEND COAL—TEMPERATURE.

Class	Rise per lb. of anthracite per hour	Rise per lb. of Wallsend per hour
	deg. F.	deg. F.
1	2·97	2·88
4	2·50	3·05
5	3·27	3·38
Average of classes 1, 4, 5 . .	2·91	3·00
Do. 6 . .	5·61	4·48

The average of the three classes of open grates, 1, 4, and 5 is nearly the same for anthracite and Wallsend. But the anthracite has the advantage for ordinary open grates in Class 1. In close stoves, Class 6, on the contrary, anthracite is clearly more efficient than Wallsend coal; and with anthracite, as with Wallsend coal, the close stoves are clearly more efficient than the open grates.

Compare now the measures of radiating force for anthracite and Wallsend coal.

TABLE X.—ANTHRACITE *versus* WALLSEND COAL—RADIATION.

Class	Radiation per lb. of anthracite per hour	Radiation per lb. of Wallsend coal per hour
	deg. F.	deg. F.
1	2·64	3·58
4	2·71	3·14
5	4·22	3·70
Average of 1, 4, and 5 .	3·19	3·47
Do. 6 . .	2·37	1·79

The radiating force attains a maximum in Class 5 of open grates, with downward or backward draught, for both kinds of fuel, and their force is the greater for anthracite, in Class 5, as well as in Class 6.

DIFFERENCES OF TEMPERATURE IN THE ROOM.

The dispositions for observing temperature at several points in the room simultaneously, afforded a means of ascertaining to what extent the temperature was varied by local conditions. Taking the results of 24 tests for the open grates of Class 1; and of 23 tests for close stoves, Class 6, in which neither C. B. Gregory's special test, nor the four long-period tests are included, the averaged temperatures at each of the four walls, at a level of 6 feet above the floor, were as follows (Table XI.). The grates and the stoves are here subdivided into such as have special air-heating contrivances, and such as are without them.

TABLE XI.—TEMPERATURE AT A LEVEL SIX FEET ABOVE THE FLOOR.

Wall of room	North	South	East	West	Averages
	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
Gross averaged temperatures:—					
Class 1. Air-heating and ventilation .	58·8	58·3	56·6	56·1	57·5
„ Non-air-heating . . .	56·9	58·0	55·6	53·8	56·1
Means	57·9	58·2	56·1	55·0	56·8
Class 6. Air-heating and ventilating .	61·2	60·0	59·1	58·7	59·8
„ Non-air-heating . . .	65·7	64·1	63·0	63·5	64·1
Means	63·5	62·1	61·1	61·1	62·0

The temperatures at the walls do not differ by more than 3° F. as between one wall and another, for the open grates of Class 1; and for the close stoves, Class 6, not more than 2½° F. The lowest temperatures are at the west walls, at which the grates and stoves were fixed. Naturally, the west walls were the least of all exposed to the heat directly radiated from the grate or the stove.

There is no apparent difference in the degree of equalisation of temperatures between the air-heating and the non-air-heating grates and stoves. That is to say, the diffusion of heat appears to be as well effected by ordinary circulation of air in the room as by the employment of special means of inducing circulation and ventilation.

Turning to the variations of temperature in the room for various levels, the differences are very marked. In the following Table (XII.) the results of 109 tests are comprised, divided into air-heating and ventilating grates and stoves, and those which are non-heating.

By this evidence, it is shown that, heated with open grates, the uppermost part of the room is much warmer—by as much as 9° in most instances—than the lowermost parts, and that close stoves give rise to even larger differences. It is also proved that the employment of means of introducing warmed air into the apartment, and of ventilating it, is not at all influential for reducing inequalities of temperature at different levels. It appears, on the contrary, to augment the actual difference that arises when no special ventilating and warming contrivances are provided. Thus, the differences of temperature for levels of 6 inches and 14 feet, are 7° and 6°·5 respectively, with and without such contrivances, for open grates; and for close stoves they are 11°·5 in one case and only 8° in the other.

It may be stated at the same time that the results of observations made on the performance (No. 28, in Table II.) of Mr. Griffin's open grate, with warming and ventilating appliances, in a private room at 27 Cadogan Square, showed a remarkable degree of

uniformity. The difference of temperature at the four sides of the room, which was 25 feet long, 18 feet wide, and 13¾ feet high, seldom exceeded 2° F.; nor did the temperature at the ceiling exceed by more than 2° F. those observed at a level of 4½ feet above the floor.

TABLE XII.—TEMPERATURE OF ROOMS AT DIFFERENT LEVELS.

Class	Air-heating and Ventilating Grates and Stoves			Non-air-heating Grates and Stoves		
	Temperatures at the following levels above the floor			Temperatures at the following levels above the floor		
	6 inches	6 feet	14 feet	6 inches	6 feet	14 feet
No.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
1	54·1	59·3	63·4	53·0	56·1	57·5
2	52·0	53·5	52·9	52·7	56·1	57·7
3	49·9	54·6	58·3	—	—	—
4	51·0	56·1	58·1	54·0	59·0	63·5
5	56·2	61·7	65·4	52·4	56·6	59·4
Averages of open grates, classes 1 to 5	52·6	57·0	59·6	53·0	56·9	59·5
No. 6 . .	50·9	57·2	62·4	63·0	68·8	71·0

Note to Table.—The differences of temperatures for Class 2, having air-warming contrivances, are exceptionally small; but the temperatures were averaged from the results of two tests only.

RISE OF TEMPERATURE AND ECONOMY OF FUEL AS AFFECTED BY AIR-HEATING AND VENTILATING APPLIANCES.

In the Table XI., the different average temperatures attained with air-heating and ventilating appliances, and without them, suggest a reference to the respective elevations of temperature, relative to the quantity of fuel consumed. The Table (XIII.) following, gives the average rise of temperature and radiation per pound of fuel consumed per hour, with air-heating appliances, and the same particulars without them, for each class of grates and stoves. The smoke-shades are added.

The influences indicated in this Table are mixed. The total averages of all classes show that Wallsend coal is used with greater economy without than with air-heating appliances; and that, on the contrary, anthracite is used with the greater economy with air-heating appliances. These contrasts are strongly marked in the results for close stoves, Class 6; whilst, for anthracite, the relative economy of air-heating appliances is visible for every class of open grates in which it is used. For Wallsend coal, the several classes of open grates show results alternately in favour of heating appliances and against them.

It may be concluded that the evidence is not decidedly for or against the use of air-heating appliances, in burning Wallsend coal, except in the case of the comparatively wasteful open grates of Class 1, with which such appliances are clearly conducive to economy; and in the case of the close stoves, Class 6, for which it does not appear that air-heating appliances, in burning Wallsend coal, are economical. In burning anthracite, it is evident that the employment of air-heating appliances in close stoves, Class 6, is economical to a considerable degree.

The radiating power, indicated in columns 6 and 7 of the Table, is materially greater

in the absence of air-heating appliances than when they are present:—for anthracite in every class; for Wallsend coal in every class except Class 5, open grates, having a downward or a backward draught, and excepting Class 6, close stoves.

TABLE XIII.—RISE OF TEMPERATURES AND RADIATIONS WITH AIR-HEATING AND VENTILATION, AND WITHOUT THEM.

Class and condition	Number of tests		Average rise of temperature per lb. per hour		Average radiation per lb. per hour		Average smoke-shade for Wallsend coal
	Wallsend	Anthracite	Wallsend	Anthracite	Wallsend	Anthracite	
1	2	3	4	5	6	7	8
			deg. F.	deg. F.	deg. F.	deg. F.	
Class 1. Air-heating . . .	9	1	3·37	3·24	2·88	1·59	3·22
,, Non-air-heating . .	10	4	2·45	2·90	4·21	4·99	2·78
Totals .	19	5	2·88	2·97	3·58	4·31	3·01
Class 2. Air-heating . . .	2	None	2·81	—	3·93	—	4·11
,, Non-air-heating . .	10	None	3·02	—	4·09	—	3·09
Totals .	12	None	2·99	—	4·07	—	3·23
Class 3. Non-air-heating . .	5	None	3·81	—	3·61	—	2·82
Class 4. Air-heating . . .	2	1	2·41	3·01	2·42	2·44	2·23
,, Non-air-heating . .	4	1	3·37	1·98	3·50	2·98	2·88
Totals .	6	2	3·05	2·50	3·14	2·71	2·66
Class 5. Air-heating . . .	11	3	3·45	3·77	4·00	3·51	2·29
,, Non-air-heating . .	7	4	3·28	2·89	3·22	4·76	3·21
Totals .	18	7	3·38	3·27	3·70	4·22	2·73
Class 6. Air-heating . . .	2	4	3·79	7·79	1·78	2·32	1·58
,, Non-air-heating . .	8	9	4·23	4·64	1·64	2·39	2·25
Totals .	10	13	4·14	5·61	1·66	2·37	2·11
Total, not including C. B. Gregory	—	—	4·48	—	—	—	—
Total averages of all classes:—							
Air-heating . . .	26	9	3·17	4·45	3·00	2·46	2·69
Non-air-heating . .	44	18	3·36	3·10	3·38	3·78	2·82

DRAUGHT AND TEMPERATURE IN THE CHIMNEY.

The velocity of the draught in the chimney, in conjunction with the temperature of the ascending air-current, supplies a means of measuring the quantity of gaseous products and air in mixture, together with the quantity of heat which passes up the chimney. In the subjoined Table (XIV.) are given averages of a number of tests for each class of open grate and for close stoves.

Here, the average temperatures of the ascending currents from the open grates (Classes 1 to 5) and those from the close stoves (Class 6) are nearly equal—say 200°; but the upward velocity, column 3, is fully one-third greater for the open grates than

for the stoves. Proportionally, the volumes of the mixed products, columns 5 and 6, are in the same ratio, and it appears that, in round numbers, the volumes, reduced for the temperature 62°, are respectively 7,500 cubic feet and 5,500 cubic feet per hour.

TABLE XIV.—DRAUGHT AND TEMPERATURE IN THE CHIMNEY.

Class	Number of tests averaged	Velocity of draught	Temperature in chimney	Volume of gases passed up the chimney per hour	
				At observed temperatures	Reduced for 62° F.
1	2	3	4	5	6
	tests	feet per minute	deg. F.	cubic feet	cubic feet
1	22	427	215	10,680	8,263
2	14	356	181	8,900	7,250
3	5	351	188	8,775	7,071
4	7	407	204	10,175	8,002
5	20	341	196	8,525	6,786
Average for open grates	14	376	197	9,400	7,471
No. 6, Close stoves .	17	275	200	6,880	5,443

The quantities of fuel consumed per hour, relative to the volumes of the upward currents, being divided into the volumes respectively, the quotients are the volumes of mixed current ascending the chimney, per pound of fuel consumed; as in the following Table (XV.). Column 5 is added to show the respective efficiencies of the classes.

TABLE XV.—VOLUME OF DRAUGHT IN THE CHIMNEY PER POUND OF COAL.

Class	Volume of gases, as at 62° F., passed up the chimney per hour	Quantities of coal consumed per hour	Gases, as at 62° F., passed up chimney per lb. of coal	Average rise of temperature per lb. of Wallsend coal consumed per hour
1	2	3	4	5
	cubic feet	lbs.	cubic feet	deg. F.
1	8,263	4·34	1,904	2·88
2	7,250	3·20	2,266	3·18
3	7,071	2·90	2,440	3·81
4	8,002	3·75	2,134	3·05
5	6,786	3·62	1,875	3·38
Averages of Classes 1 to 5	7,471	3·56	2,099	3·26
No. 6	5,443	4·70	1,158	4·48

The contrast between the quantities of gases passed up the chimney from open grates (Classes 1 to 5) and from close stoves (Class 6) is here very strongly put in evidence. It is shown that whilst, in round numbers, the open grates pass up 2,100 cubic feet per pound of fuel consumed, the close stoves pass up only 1,160 cubic feet, or about half the quantity rising from the open grates. It it easily understood, therefore—what is well known in ordinary experience—that ventilation is more abundantly effected by means of open grates than by close stoves.

It is to be remarked, further, that the grates (Class 3, under-fed) which pass up the maximum quantity of gaseous mixture per pound of coal consumed—2,440 cubic feet—are precisely those which develop the maximum efficiency, 3·81 degrees rise of temperature per pound of coal, notwithstanding that the combustion is not generally of the most nearly complete character.

And it is still more notable that the open grates of Class 5, having a downward or a backward direct draught, and having the minimum quantity of mixed current up the

chimney—1,875 cubic feet per pound of fuel—rank next in efficiency to those, Class 3, which dispose of the maximum current. They raise the temperature 3·38 degrees per pound of fuel burnt per hour.

Thus, finally, the two classes which agree in directing the draught through the incandescent fuel—upwards in Class 3, and contrariwise in Class 5—and which differ in being associated with the maximum and the minimum draughts respectively, are precisely those which together exhibit the maximum efficiencies for open grates. Herein lies the germ of a problem which awaits solution.

DILUTION OF THE GASEOUS CURRENT IN THE CHIMNEY.

Supposing that the fuel is perfectly burned, it may, for the present purpose, be assumed that 150 cubic feet of air at 62° is consumed in burning one pound of fuel, and that the gaseous products of combustion evolved occupy equal volumes at equal temperatures. But inasmuch as an average of 2,100 cubic feet of upward current passes off, for each pound of fuel consumed in open grates, it follows that the direct chemical products of combustion are diluted to the extent of 14 volumes; that is, that the direct chemical products are mixed with thirteen times their volume of air. For close stoves, having currents of 1,160 cubic feet at 62° per pound of coal, the dilution with air is carried to the extent of about eight times the volume of gases chemically evolved; that is, these gases are mixed with seven times their volume of air.

General Composition of the Current.

	Gaseous products	Atmospheric air
Open grates . . .	One-fourteenth, or 7 per cent.	93 per cent.
Close stoves . . .	One-eighth, or 12½ per cent.	87½ per cent.

The question arises, how much heat is carried off by the currents up the chimney?

HEAT CARRIED UP THE CHIMNEY.

The quantity of heat carried up the chimney, usually reckoned, for the most part, as wasted heat, is readily calculated in terms of the volume and the specific heat of the current, and the rise of temperature. Since the current consists, as has just been seen, for by far the greater part, of atmospheric air, its specific heat may be taken as that of air, namely, 0·238. Their specific gravities may also be taken as equal. Calculating for open grates, as 1 lb. of air at 62° F. has a volume of 13 cubic feet, the weight of 2,100 cubic feet passed off for 1 lb. of coal is (2,100÷13=) 161 lbs., and the quantity of heat carried off per pound of coal is (161 × 0·238=) 38·3 units for 1° rise of temperature. But the average temperature of the escaping current was seen to be 197°; and, deducting the external temperature, 40°, given in column 3 of Table, the rise of temperature was (197−40=) 157 degrees. The total quantity of heat of combustion carried off was, on this basis (38·3 units × 157=), 6,013 units for each pound of coal. The heat of combustion of coal of average composition, which may for the present be adopted, is equal to 14,000 units, and it follows that the wasted heat carried up the chimney is (6,013 × 100 ÷14,000=) 43 per cent. of the total heat of combustion.

From close stoves, the quantity of air passed off by the chimney is 1,160 cubic feet for 1 lb. of coal, weighing (1,160÷13=) 89 lbs.; and the heat required to raise this weight of air 1° in temperature is (89 × ·238=) 21 units. The average temperature in the

chimney was 200°, and deducting the external temperature, which averaged 42°, the rise of temperature was 158°. The quantity of heat carried off was (21 units × 158 =) 3,318 units for each pound of coal, equivalent to (3,318 × 100 ÷ 1,400 =) 24 per cent. of the total heat of combustion.

The proportion of the total heat of combustion exported through the chimney, thus calculated, is

For open grates . . .	43 per cent., or upwards of two-fifths of the total heat.
For close stoves . . .	24 per cent., or nearly one-fourth do. do.

It is here assumed that the fuel is completely burned. In so far as the combustion is incomplete, the percentage proportions of exported heat must be greater than those above deduced.

DISTRIBUTION OF THE HEAT OF COMBUSTION.

Forty-three per cent. of the total heat of combustion of coal—and coke and anthracites may be included—from open grates, has been accounted for, as exported up the chimney; and 24 per cent. from close stoves. The remaining 57 per cent. and 76 per cent. respectively, are dispersed by conduction through the back and sides of the grate, by air-convection at the heated surfaces of the grate, by radiation, and by a remainder due to incompleteness of combustion. Of these, the heat that is radiated from the open fire, or the close stove, constitutes the largest proportion. According to the results of M. Péclet's experiments, one-fourth of the total heat of combustion of wood was radiated; and one-half of that of charcoal: flaming fuel in the first case, flameless in the second case. For the case of coal, it may be accepted that the proportion of heat radiated from the fuel varies between these limits.

To form, incidentally, an estimate of the proportion of heat absorbed in raising the temperature of the air in the room, let it be assumed that all the air which goes up the chimney is previously heated to the temperature of the room :—that is, taking averages, that 2,100 cubic feet at 62°, per pound of coal, for open grates, and 1,160 cubic feet for close stoves, are raised from the temperature of the external atmosphere to the average temperature in the room. Such elevation of temperature would, according to Table IV., page 71, have taken place from 40° to 57° for open grates, and from 46° to 66° for close stoves, or through 17° and 20° respectively. Following the lead of previous calculations, the heat required to raise 2,100 cubic feet (at 62°), or 161 lbs., of air, through 17° would be (38·3 units × 17° =) 651 units; and to raise 1,160 cubic feet (at 62°), or 89 lbs., of air through 20°, the heat absorbed would be (21 units × 20° =) 420 units. These quantities are respectively 4·65 per cent. and 3 per cent. of the whole heat of combustion of one pound of coal. These would be the percentages of the total heat utilised in raising the temperature of the air in the room, even supposing the whole of the air that enters and leaves the room to be continuously replaced by fresh air. Evidently, it is not in the direction of the simple warming of the air in the room, that the greatest consumption of heat is to be traced.

The enclosing walls, floor, and roof of the rooms are, in fact, the principal absorbents of heat. It may be assumed that they are, in the course of the trial, raised in temperature to nearly, if not equal to, the maximum observed temperature of the air close to them. How much heat is required to effect this rise of temperature? The smaller testing rooms are 15 feet square, and 15 feet high to the top of the walls, making, with the floor of concrete, five squares of 15 feet each way, and having a total area of (15 feet × 15 feet × 5 =) 1,125 square feet. The walls and the floor are 6 inches in thickness, and have a solid content equal to (1,125 × 0·5 =) 562½ cubic feet, not

allowing for the spaces occupied by doors and windows. These are amply compensated by the ceiling as absorbing material, which is not taken into the calculation. Besides, they transmit heat to the external air. Allowing 130 lbs. weight per cubic foot for the concrete of which the walls are built, the gross weight of material of walls and floor to be warmed is ($562\frac{1}{2} \times 130 =$) 73,125 lbs. The specific heat of concrete is, say, 0·21, and the quantity of heat required to raise the mass throughout by 1° of temperature would be ($73,125 \times ·21 =$) 15,356 units. The average total rise of temperature at the walls, deduced from the averages of the last hour (column 15 of the large Table III.), was for each class as follows (Table XVI.):—

TABLE XVI.—RISE OF TEMPERATURE AT THE WALLS.

Class	Average initial temperature	Average maximum temperature at walls	Maximum rise of temperature
No.	deg. F.	deg. F.	deg. F.
1	47·2	61·7	14·5
2	47·1	59·2	12·1
3	45·0	58·2	13·2
4	48·2	63·5	15·3
5	48·3	64·8	16·5
AVERAGES OF NOS. 1 TO 5.	47·2	61·5	14·3
6	49·8	68·8	19·0

Showing a maximum rise of temperature averaging for open grates, 14·3° (say 14°), and for close stoves, 19°. The quantity of heat required to raise the temperature of the walls of the smaller rooms, through 14°, would be ($15,356 \times 14 =$) 214,984 units. But, considering that the wall is not uniformly heated through, and that the elevation of temperature at the outside surface is a minimum, take one-half of this quantity of heat, or 107,492 units, as the actual expenditure. This allowance compensates also for the coincidence of testing in two neighbouring rooms at the same time, when the party-wall is heated from both sides. Dividing the reduced quantity of heat by 14,000 units, the heat of combustion of 1 lb. of coal, the quotient gives 7·68 lbs. of coal as that the combustion of which is necessary to heat up the walls, independently of what is consumed additionally in order to maintain the temperature against losses by radiation and conduction externally. As the duration of the trials averaged five hours, the estimate shows a consumption of coal at the rate of 1·54 lbs. per hour for the special work of heating up the walls of the smaller testing rooms for open grates. The consumption amounts, at this rate, to 42 per cent. of all the coal consumed in open grates. For close stoves, the maximum rise of temperature, 19°, involved a consumption of ($1·54 \times 19 \div 14 =$) 2·09 lbs. per hour, being 54 per cent. of all the coal consumed in close stoves. For the larger testing room, having double the capacity of the smaller rooms, the consumption of coal for the same purpose must be at least one-half more per degree of rise of temperature than what is required for the smaller rooms. But, the elevation of temperature in the larger room was considerably less than in the smaller rooms; and therefore the same quantity of coal, 1·54 lbs. per hour, or 42 per cent., is now taken, for the larger room as for the smaller rooms, as that which is required to raise the walls to the maximum temperature for open grates; and 2·09 lbs. per hour, or 54 per cent., for all the rooms, for close stoves.

It may be concluded that the heat of combustion of the fuels consumed was distributed in proportions generally as follows (Table XVII.).

The third items of the distribution of the heat—the loss or waste of heat for open grates and close stoves—are very nearly in the same proportion to each other as the respective elevations of temperature given in column 6 of Table IV., page 71, inasmuch as

whilst the elevations of temperature are in round numbers 11° and 18°, the relative losses are 15 per cent. and 22 per cent. This is a natural relation, showing, as might have been anticipated, that the losses are greater as the elevations of temperatures are greater.

TABLE XVII.—DISTRIBUTION OF THE HEAT OF COMBUSTION OF THE FUEL.

	Open grates	Close stoves
	per cent.	per cent.
Heat carried up the chimney	43	24
Radiated and conducted heat absorbed by the walls	42	54
Heat lost by radiation and conduction externally, and heat lost by imperfection of combustion	15	22
	100	100

INDIVIDUAL RESULTS OF TESTS OF GRATES AND STOVES.

The tests of open grates and close stoves having been passed in general review in classes, they may be noticed individually. In the following Table (XVIII.), results of the tests made in the testing houses at South Kensington with Wallsend coal and with anthracite, are arranged in the order of efficiency in heating or raising the temperature of the room, expressed in degrees of rise of temperature per pound of fuel consumed per hour (column 3). The measures of radiation are added, in column 4, expressed in degrees per pound of fuel consumed per hour. The average smoke-shades are entered in column 5. The averages deduced in these Tables have been employed in the previous Tables.

TABLE XVIII.—INDIVIDUAL RESULTS OF TESTS.

CLASS I. *Open Grates, having ordinary bottom grids and upward draught.*

No. of test	Exhibitor and grate	Average rise of temperature per lb. of coal per hour	Average radiation per lb. of coal per hour	Average smoke-shade
1	2	3	4	5
	AIR-HEATING.—*Wallsend Coal.*	deg. F.	deg. F.	
10	T. Potter & Sons. Thermhydric grate	5·16	5·35	3·50
19	A. B. Verrier. Comet grate	4·69	2·00	3·66
20	Do. do.	3·04	1·56	2·75
21	Rosser & Russell. Firebrick lining, fluted	3·85	5·71	1·92
23	G. Haller & Co. Kohlhofer's hot-air stove	3·73	2·41	3·00
3	The British Sanitary Company. Enclosed grate	3·14	1·64	4·71
11	Perceval and Westmacott. Parlour stove	2·98	2·98	2·67
26	E. H. Shorland (G. L. Shorland's patent). Manchester grate, firebrick lining	2·16	1·77	2·87
6	J. Wright & Co. Hygienic ventilating stove	1·55	1·46	3·89
	Averages	3·37	2·88	3·22
	Anthracite.			
9	J. Wright & Co. Hygienic ventilating stove	3·24	1·59	—
	NON-AIR-HEATING.—*Wallsend Coal.*			
17	W. P. Taylor. Perforated firebrick back	3·12	4·00	2·62
22	Do. do.	2·86	5·42	3·50
15	F. Nash. Back downward draught, to deposit soot	2·61	3·13	1·27
16	Do. do.	2·70	—	2·59
18	The Radiator Range Company. Projecting grate and combustion chamber	2·23	3·39	—
25	Do. do.	2·87	4·98	—
14	W. Poore & Co. Triumph stove: firebrick lining, and blower	2·40	3·08	4·11
8	M. Perret. Radiating fire-grate: firebrick lining and roof	2·00	3·82	3·55
1	J. G. Gray. Sloping perforated back	1·90	4·25	2·79
27	A. C. Engert. Solo grate: half-barrel formed grate, stoked behind	1·85	2·91	1·81
	Averages	2·45	4·21	2·78
	Anthracite.			
2	Barnard, Bishop and Barnards. Firebrick lining	4·90	4·66	—
7	Perret. Radiating fire-grate: firebrick lining and roof	2·74	4·29	—
4	Do. do.	2·55	6·11	—
13	W. Poore & Co. Triumph stove: firebrick lining and blower	1·42	1·97	—
	Averages	2·90	4·90	—

TABLE XVIII.—INDIVIDUAL RESULTS OF TESTS—(*continued*).

CLASS II. *Open Grates, having solid floors, adapted for slow combustion, and upward draught.*

No. of test	Exhibitor and grate	Average rise of temperature per lb. of coal per hour	Average radiation per lb. of coal per hour	Average smoke-shade
	AIR-HEATING.—*Wallsend Coal.*	deg. F.	deg. F.	
40	Steel & Garland. Wharncliffe grate	3·25	5·22	3·86
37	Marshall, Watson & Moorwood. Harleston grate	2·37	2·64	4·36
	Averages	2·81	3·93	4·11
	NON-AIR-HEATING.—*Wallsend Coal.*			
44	J. B. Petter. Nautilus grate	4·12	3·38	2·81
39	Do. do.	3·73	3·50	3·89
46	Barnard, Bishop & Barnards. Glow-fire	4·00	5·04	2·36
33	Do. do.	3·00	6·44	3·77
38	Doulton & Co. Fire-place of firebrick slabs	3·78	2·59	1·33
41	F. Edwards & Son. Arnott's grate: downward burning	3·22	2·48	3·10
47	T. Mitchell. Common grate, with fireclay lining and floor	3·56	5·98	3·60
50	Do. do.	2·09	?	2·40
42	F. Edwards & Son. Downward-burning grate	3·09	2·75	2·28
43	Do. do.	1·46	3·07	3·00
36	The Derwent Foundry Company. Abbotsford grate	3·07	5·73	4·21
34	Barnard, Bishop & Barnards. Bartlet grate (Wallsend coal and coke)	2·55	?	3·00
45	Frost & Winfield. Fire-lumps and baffle-roof	1·56	4·05	4·43
	Averages	3·02	4·09	3·09

CLASS III. *Open Grates, under-fed: supplied with fresh fuel beneath the incandescent fuel.*

No. of test	Exhibitor and grate	Average rise of temperature per lb. of coal per hour	Average radiation per lb. of coal per hour	Average smoke-shade
	NON-AIR-HEATING.—*Wallsend Coal.*	deg. F.	deg. F.	
56	W. S. Melville. Common grate, under-feeding shovel	4·93	3·50	4·14
53	E. R. Hollands. Under-fed, movable grid	4·90	3·62	2·52
57	E. H. Shorland (G. L. Shorland's patent). Princess Louise grate, under-feeding shovel	4·71	4·68	3·00
55	Brown & Green. Under-fed by a pusher	2·85	3·72	2·12
58	Yates, Haywood & Co. Under-fed, movable grid	1·65	2·54	2·31
	Averages	3·81	3·61	2·82

TABLE XVIII.—INDIVIDUAL RESULTS OF TESTS—(*continued*).

CLASS IV. *Open Grates, fed from the back, or from the sides, or from hoppers.*

No. of test	Exhibitor and grate	Average rise of temperature per lb. of coal per hour	Average radiation per lb. of coal per hour	Average smoke-shade
	AIR-HEATING.—*Wallsend Coal.*	deg. F.	deg. F.	
63	J. M. Stanley. Hopper-fed: downward draught .	2·66	1·81	2·24
61	Musgrave & Co. The Ulster grate: back hopper .	2·16	3·02	2·22
	Averages	2·41	2·42	2·23
	Anthracite.			
64	J. M. Stanley. Hopper-fed: downward draught .	3·01	2·44	—
	NON-AIR-HEATING.—*Wallsend Coal.*			
65	H. E. Hoole. Side hoppers, and reflector . .	6·33	5·06	2·55
60	A. C. Engert. Coking box at back	2·35	3·56	2·92
62	The Coalbrookdale Company. Gassius grate: solid floor, back hopper	2·34	2·81	1·76
67	Archibald Smith & Stevens. Wonderful grate: back hopper, downward draught	2·18	2·59	4·29
	Averages	3·37	3·50	2·88
	Anthracite.			
66	Archibald Smith & Stevens. Wonderful grate: back hopper, downward draught. . . .	1·98	2·98	—

TABLE XVIII.—INDIVIDUAL RESULTS OF TESTS—(*continued*).

CLASS V. *Open Grates, having downward, backward, or lateral draught.*

No. of test	Exhibitor and grate	Average rise of temperature per lb. of coal per hour	Average radiation per lb. of coal per hour	Average smoke-shade
	AIR-HEATING.—*Wallsend Coal.*	deg. F.	deg. F.	
81	Steel & Garland. Kensington grate: firebrick lining and floor; backward and lateral draught .	4·58	3·60	3·66
75	M. Feetham & Co. Hurst grate; backward and downward draught	4·22	4·53	(?)
73	Do. do. .	4·12	7·01	1·41
80	J. Moore. Backward and downward draught .	4·10	3·89	2·50
86, 87	W. I. Henry. Reeve & Henry's Smoke-purifyer. Filter-chamber, adapted to a hob-grate. Mean of two	3·92	5·06	1·68
69	Captain T. E. Clarke. Downward draught . .	3·60	2·76	1·75
70	Do. do. . .	2·18	3·24	2·93
76	Yates, Haywood & Co. Redmayne's grate: firebrick lining and floor	3·29	3·55	4·73
91	W. I. Henry. Reeve & Henry's Smoke-purifyer. Filter-chamber, adapted to a register-grate . .	3·16	3·44	0·91
72	M. Feetham & Co. Dog-grate with fire-basket: backward and downward draught . . .	2·63	3·71	1·19
71	The Derwent Foundry Co. Jobson's grate: firebrick lining; draught downwards and backwards	2·14	3·25	3·16
	Averages	3·45	4·00	2·29
	Anthracite.			
74	M. Feetham & Co. Hurst grate	5·03	5·02	—
77	Yates, Haywood & Co. Redmayne's grate . .	4·95	4·21	—
84	Steel & Garland. Kensington grate	1·32	1·31	—
	Averages	3·77	3·51	—
	NON-AIR-HEATING.—*Wallsend Coal.*			
88	T. E. Parker. The Vencedor grate: firebrick lining and floor; downward and backward draught .	5·43	2·79	2·20
89	Do. do. .	4·70	2·84	2·37
79	Deane & Co. Crane's grate: firebrick lining, downward draught	4·00	5·09	3·00
92	Do. do. .	2·22	3·51	4·45
90	J. Cornforth. Hollow fire-bars: backward draught	3·00	2·56	3·50
82	Clark, Bunnett & Co. Ingram's Kaio-Kapnos grate: firebrick lining and floor; backward draught .	2·04	3·40	3·31
93	W. Lawrence. Backward draught into a combustion chamber	1·59	2·33	2·72
	Averages	3·28	3·22	3·21
	Anthracite.			
68	The Coalbrookdale Co. The Kyrle grate. Backward draught at the bottom; firebrick lining and floor	4·53	7·78	—
85	Brown & Green. Luton grate: firebrick lining, sloped grid; draught through back . . .	2·88	4·03	—
78	Deane & Co. Crane's grate	2·60	4·07	—
83	Clark, Bunnett, & Co. Ingram's grate . . .	1·55	3·15	—
	Averages	2·89	4·76	—

Table XVIII.—INDIVIDUAL RESULTS OF TESTS—(*continued*).

Class VI. *Close Stoves.*

No. of test	Exhibitor and stove	Average rise of temperature per lb. of coal per hour	Average radiation per lb. of coal per hour	Average smoke-shade
	Air-Heating.—*Wallsend Coal.*	deg. F.	deg. F.	
97	H. J. Newcome. Tubular air-warmer	4·80	2·02	2·00
118	J. T. Farwig & Co. Calorigen stove	2·77	1·53	1·16
	Averages	3·79	1.78	1·58
	Anthracite.			
123	F. Lönholdt. Anthracite stove	11·51	2·44	—
111	W. Stobbs. Crystal ventilating stove	11·33	3·67	—
114	H. Hunt. Hygiene ventilating stove	5·00	2·36	—
126	H. J. Piron. Hot-air stove and ventilator	3·32	0·81	—
	Averages	7·79	2·32	—
	Non-Air-Heating.—*Wallsend Coal.*			
104	Yates, Haywood & Co. Miser: two pillars	6·80	2·41	4·48
105	J. Cornforth. Little Wonder (heating surface more than doubled by long smoke-pipe, 9°·04 rise per lb. of coal, reduced to 6° per lb.)	6·00	2·98	0·69
116	Steel & Garland. Miser: four pillars	5·16	2·81	2·36
130	J. Dunnachie. Star heating stove	4·26	0·72	1·33
120	Do. do.[1]	—	—	—
127	R. W. Crosthwaite. Armstead-Gregory stove	3·76	1·64	0·46
119	The Sunlight Stove Company. Sunlight stove	2·95	1·75	6·31
95	C. B. Gregory. Smoke-burning furnace	2·48	0·54	0·00
100	The Derwent Foundry Company. Jobson's gill stove	2·19	0·24	2·35
	Averages	4·23	1·64	2·25
	Anthracite.			
102	H. Hunt. Economy portable stove	8·11	2·78	—
113	Do. Crown Jewel stove	6·66	2·00	—
107	R. W. Crosthwaite. Armstead stove, No. 1	5·41	2·80	—
108	Do. do. No. 2	4·42	5·16	—
109	Do. do. No. 4	4·27	2·61	—
106	Do. do. No. 3	3·23	1·40	—
110	Do. do. No. 5	2·22	1·42	—
128	Brown & Green. Albion stove	4·16	2·38	—
103	H. Hunt. Economy: base burner	3·32	1·00	—
	Averages	4·64	2·39	—

[1] Omitted here (very bad stoking).

TABLE XVIII.—INDIVIDUAL RESULTS OF TESTS—(*continued*).

CLASS VI. *Slow-combustion tests for long periods.*

No. of test	No. of testing room	Exhibitor	Duration of test	Fuel consumed per hour	Rise of temperature				Radiation per lb. of coal per hour
					1st day	2nd day	Mean	Mean per lb. of coal	
			hours	lbs.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
96	3	Musgrave & Co.	24	Coke, 2·22	15·66	2·84	9·25	4·17	9·85
98	5	B. J. Klingenberg	27½	Wallsend coal, 2·31	10·80	12·75	11·77	5·09	2·00
99	3	C. Portway & Sons	24	Coke, 2·02	17·66	11·83	14·75	7·30	12·91
124	5	F. Lönholdt	23½	Anthracite, 1·11	12·16	16·43	14·88	13·41	11·18

Four close stoves were tested for periods of upwards of 20 hours continuously, making Nos. 96, 98, 99, and 124 in Table No. III. The mean rise of temperatures, column 7, is taken as relative, not absolute. The values for rise of temperature in tests Nos. 98 and 124, conducted in No. 5 room, are equivalent values, being 1¼ times the observed values, in order to compare on equal footing, as before explained, with the observed values in tests Nos. 96 and 99, which were conducted in a smaller room.

REMARKS ON THE FOREGOING TABLE.

Class I. *Air-Heating and Ventilation: Wallsend Coal.*—T. Potter & Son's thermhydric grate stands at the head of the list for efficiency, in virtue of the great expansion of radiating and air-warming surface developed in the hot-water tubes to the right and the left of the fire-place, whilst excessive temperature of heated air is obviated. In A. B. Verrier's 'Comet' grate, the draught is partly taken through the back, into a combustion-chamber, where heat is developed and carried off by the air discharged into the room. Rosser & Russell have developed to a great degree firebrick absorbing and radiating surface, in employing a fluted back with hollow sides. Hence their relatively high degree of radiation and moderate smoke-shade. G. Haller & Co. have, in Kohlhofer's hot-air stove, developed air-warming surface to an extreme degree. Hence the comparatively high degree of efficiency, and, incidentally, an inferior radiating power, consequent on the great expansion of the heating area. The British Sanitary Company have probably made the most of the principle of active radiation, in the isolated fire-basket, which radiates heat all around. But the smoke-shade is heavy. Perceval & Westmacott, in their Parlour Stove, ingeniously combine a cooking-oven placed directly over the fire. The taper form of the conduit pipes which lead the gaseous products from the fire, by which the gases are drawn together, is likely to act in promoting combustion. The 'Manchester' grate, exhibited by E. H. Shorland, possessed little radiating power, with a moderate rise of temperature; and it was but moderately successful in preventing smoke. J. Wright & Co.'s Hygienic Ventilating Stove, with its iron back and cooling surfaces, did not appear to be very active in efficiency or in radiation, nor effective in the prevention of smoke.

Class I. *Air-Heating: Anthracite.*—The only test under these conditions was made with J. Wright & Co.'s Hygienic Stove—a much better performance than that effected on the same grate burning Wallsend coal.

Class I. *Non-Air-Heating: Wallsend Coal.*—W. P. Taylor, in employing a gilled fireclay back in his first test and a firebrick back in the second test—made in both cases with perforations and interstices for the influx of air into the fire from the back—

certainly made a bright and active fire, with considerable radiating power. The fire was supplied with external air introduced through a grating in the hearth. By this means, draughts from the door and window were prevented. But the means of preventing smoke were not sufficient. Thomas Nash contrived, by conducting the hot products downwards behind the back of the grate, to develop radiating power; but the soot-collecting box at the back did not appear to be of much service in controlling the smoke-shade. The Radiator Range Company's appliances, consisting of a preliminary combustion-chamber applied to the back of the grate within the fire-place, was effective for radiation. The tests were scarcely sufficient to settle the heating and smoke-preventing qualities. The 'Triumph' stove of W. Poore & Co., firebrick lined, succeeded in radiating heat; but the smoke-prevention was imperfect. The action of M. Perret's radiating grate was based entirely on the radiating power of the firebrick, which, besides being employed as lining, was employed also to form a roof or reverberator—useful, no doubt, for burning anthracite, but not favourable for burning smoke-making coal, of which the smoke-making gases were rapidly separated by the reverberated heat from the tile overhead. J. G. Gray's sloping perforated back admitted air into the body of a shallow fire from behind. It does not bear a favourable comparison in any respect with Mr. Wavish's system (Nos. 29 to 32, in Table I.), in which air was carried into the heart of the fire, and smoke was materially diminished. A. C. Engert's 'Solo' grate, of barrel form, is useful for burning large supplies of fuel stoked from behind, and pushed forward towards the front as required. It is questionable whether this form of grate, though effective to some extent in preventing smoke, admits of the complete combustion of the fuel.

Class I. *Non-Air-Heating: Anthracite.*—The anthracite grate of Barnard, Bishop & Barnards, was very effective in warming as well as in radiation—in virtue, no doubt, of the firebrick lining. M. Perret's radiating fire-grate worked better in burning anthracite than Wallsend coal:—in radiating power, as well as in efficiency, the reverberating roof being useful in brightening the fire and maintaining it in a state of incandescence at the surface. W. Poore & Co.'s stove did not work favourably with anthracite. It appeared to be of scarcely sufficient capacity for properly burning that fuel.

Class II. *Air-Heating and Ventilation: Wallsend Coal.*—The 'Wharncliffe' grate of Steel & Garland was suitably formed, with a bevilled canopy, utilised as a compact air-warming chamber, well stocked with gills, which were cast on the back of the grate. A considerable rise of temperature was effected, and a considerable degree of radiation took place:—radiated heat, no doubt, being reflected by the inner slopes of the canopy. There was not any special means of burning the smoke, which was rather heavy. The 'Harleston' grate of Marshall, Watson & Moorwood, resembles constructionally the 'Wharncliffe' grate above noted; but it differs from this in the construction of the canopy without any internal gills for warming fresh air; also in the building of a roomy recess behind the grate, as an air-warming chamber. Here, the compactness and the close and developed heating surface of Steel & Garland's grate are wanting; and this difference may explain the inferiority of the performance of Marshall & Co.'s grate.

Class II. *Non-Air-Heating: Wallsend Coal.*—In the 'Nautilus' grate, J. B. Petter combined originality and efficiency. The open space about the grate, together with the openness of its structure, and its basis of firebrick, afforded free play for radiation, direct and returned. These conditions may help to account for the 'Nautilus' grate standing first in Class II. for efficiency. The average smoke-shade, nevertheless, was comparatively heavy, although the air and the gases from the fire were closely brought together above the fire, and were favourably associated for the completion of combustion. It is probable that the divided flue was unfavourable for smoke-prevention, as the air might have passed off one way and the gases another; at the same time the intermixture was not promoted by the form of the outflows, which were simply short pipes, one at each

side. The 'Glow-Fire' of Barnard, Bishop & Barnards was efficient; and, in addition, it exhibited the maximum radiating power in its class. The firebrick roof, or baffle, no doubt promoted the radiating action, but it did not appear to promote the combustion of the gases rising from the fire. It acted, probably, rather as a distillatory agent, in raising the gases quickly from fresh fuel, than in burning them after they were formed; for, although air was delivered through the back, over the fire, to meet the gases, the length of run under the baffle was too short to admit of the gases and air being sufficiently intermixed. Doulton & Co.'s Tile grate, next in efficiency, had, like the 'Nautilus' grate, the advantage of openness, and freedom for direct upward radiation from the fire. F. Edwards & Son had Dr. Arnott's downward-burning stove tested with their own system of burning downwards. In grates of their own design, the smoke-shades were moderate. But the grates were comparatively slow-burning, and of course could not be forced. The fireclay-lined grate of T. Mitchell had a considerable smoke-shade; but the radiation also was considerable. The 'Abbotsford' grate of the Derwent Foundry Company had a heavy smoke-shade, but considerable radiating power. The 'Bartlet' grate of Barnard, Bishop & Barnards is of the same kind as the two preceding grates, and it was nearly as efficient. The least efficient grate in Class II. is that of Frost & Winfield, which resembles the 'Glow-Fire,' but is distinguished from it chiefly by the inflow of air into the fire through the back slab at the bottom, where the 'Glow-Fire' is close.

Class III. *Non-Air-Heating: Wallsend Coal.*—W. J. Melville, under-feeding with a peculiarly formed shovel, attained a high degree of efficiency; but his smoke-shade was heavy. E. R. Hollands' grate, mechanically under-feeding, was also very efficient, and the smoke-shade was moderate. The 'Princess Louise,' exhibited by E. H. Shorland, with an under-feeding shovel, was likewise efficient. Brown & Green's grate, under-fed by a pusher, was not so efficient as the grates just named, but it made the lowest smoke-shade in its class. An under-fed grate, by Yates, Haywood & Co., resembled E. R. Hollands' grate. It was tested experimentally.

Class IV. *Air-Heating: Wallsend Coal.*—J. M. Stanley's hopper-fed grate showed a comparatively low smoke-shade; also a moderate degree of efficiency, with a low radiating power:—to be expected from the rather close disposition of the grate. In the 'Ulster' grate, of Musgrave & Co., the fresh fuel was introduced into the fire at the back, for its whole depth. Accordingly, the most of the gaseous products passed through incandescent fuel, and the smoke-shade was light.

Class IV. *Air-Heating: Anthracite.*—J. M. Stanley's hopper-fed grate acted efficiently with anthracite:—more efficiently than with Wallsend coal.

Class IV. *Non-Air-Heating: Wallsend Coal.*—H. E. Hoole's grate made decidedly the highest efficiency and radiating power of all the grates of its class; due to the excellent conical reflector by which the heat radiated obliquely from the fire was effectively reflected into the room. The back coaling-box of A. C. Engert did not sufficiently control the preparatory process of distillation, as aimed at in grates of this class. The Coalbrookdale Company's 'Gassius' grate, delivering fresh coal at the bottom of the fire-place, was the most efficient of its class in reducing the average smoke-shade; contrasting favourably with Archibald Smith & Stevens' 'Wonderful' grate, in which the smoke-shade was maximised. Here the coal was delivered to the fire at the upper part of the back, and so the distilled gases did not thoroughly traverse the fire, and they escaped partly unconsumed. On the contrary, in the 'Ulster' grate, of Musgrave & Co., already noticed, the fresh coal was introduced into the fire at the back for its whole depth. Accordingly a less proportion of the distilled gases escaped unconsumed than in the 'Wonderful' grate, and the smoke-shade was much lighter, nearly approaching that of the Coalbrookdale grate, in which also the fuel was charged at a low level.

Class IV. *Non-Air-Heating: Anthracite.*—Archibald Smith & Stevens' 'Wonderful' grate acted with results corresponding to those already noticed for Wallsend coal in the same grate.

Class V. *Air-Heating: Wallsend Coal.*—Steel & Garland's 'Kensington' grate stands first in this section for efficiency; but the smoke-shade is heavy, probably because the deflecting screen around the interior of the fire-place is not carried far enough down into the fire to drive the gaseous products well through the incandescent fuel. In the 'Hurst' grate, by M. Feetham & Co., the draught is carried down through the fire, and the effect is a very light shade of smoke, with much radiation. J. Moore, on the same principle, shows nearly as much efficiency as M. Feetham & Co., but less radiating power and a darker smoke-shade. The comparatively greater depth of smoke-shade may be due to the fact, that Mr. Moore carries the current from above the fire directly through to the back-flue, whilst Mr. Feetham takes it down to the base to meet with the hot currents from the sides. Reeve & Henry's Smoke-Purifyer, exhibited by W. I. Henry, in a register-grate and a hob-grate, showed a light smoke-shade. The draught is carried through the fuel and through the back into a filter-chamber filled with iron-turnings. Thus, there are two means of reducing the smoke. Captain T. E. Clarke is moderate in efficiency, radiation, and smoke-shade. Redmayne's grate, by Yates, Haywood & Co., showed a heavy smoke-shade. The 'Dog' grate, by M. Feetham & Co., makes a very light smoke-shade. Jobson's grate, by the Derwent Foundry Company, was the lowest in efficiency of its section, whilst the smoke-shade was considerable.

Class V. *Air-Heating: Anthracite.*—The 'Hurst' grate, by M. Feetham & Co., acted with a greater degree of efficiency, and of radiation, in burning anthracite than in burning Wallsend coal. So also did Redmayne's grate, by Yates, Haywood & Co. The 'Kensington' grate, by Steel & Garland, on the contrary, was very low in efficiency and radiation.

Class V. *Non-Air-Heating: Wallsend Coal.*—The 'Vencedor' grate, by T. E. Parker, stands at the head of Class V., for efficiency. Crane's grate, exhibited by Deane & Co., was proved to have a fair degree of efficiency, with good radiating power; but it showed a comparatively heavy smoke-shade. J. Cornforth's grate made smoke of a moderately deep shade. Ingram's grate, by Clark, Bunnett & Co., was but moderately efficient. W. Lawrence's grate, with a back combustion-chamber, was still less efficient.

Class V. *Non-Air-Heating: Anthracite.*—The 'Kyrle' grate of the Coalbrookdale Company showed a great degree of efficiency, and of radiating power. Moderate results were derived from tests of Brown & Green's 'Luton' grate, the 'Crane' grate of Deane & Co., and Ingram's grate, by Clark, Bunnett & Co.

Class VI. *Air-Heating: Wallsend Coal.*—The efficiency of H. J. Newcome's Tubular Air-warmer, and the low temperature in the chimney, 90°, are due to the greatly developed radiating and conducting surface of his tubes; and the moderate degree of smoke was arrived at partly by the deposit of soot in the circulating pipes. The temperature, 90°, contrasts with the probable temperature, 200°, which would have been reached in the chimney if the draught had been direct. The 'Calorigen' stove, by J. F. Farwig & Co., is but moderately efficient,—for want of surface, no doubt,—as the smoke-shade is very light, and the combustion was good.

Class VI. *Air-Heating: Anthracite.*—F. Lönholdt's base-burner stove takes the lead in efficiency as a close anthracite-stove. By conducting the hot gaseous products to the bottom, and developing a large surface for warming air, Mr. Lönholdt was enabled to deliver from the stove as much as 6,000 cubic feet of air per hour, at a

temperature of from 200° F. to 220° F. The 'Crystal' Ventilating stove, exhibited by W. Stobbs, also a base-burner, was very efficient. The 'Hygiene' stove of H. Hunt, a base-burner, had a considerable degree of efficiency. It differed from Mr. Stobbs' 'Crystal' stove, in bringing in fresh air from without to be warmed and delivered into the room, whereas the 'Crystal' stove drew its supply from the room for warming. H. J. Piron's stove, in which the products of combustion passed at once upwards and were led off, was the least efficient of the four ventilating stoves burning anthracite; whilst its radiating action was very meagre—in consequence, no doubt, of the superfluous pains which were taken to prevent radiation, by lining the case of the stove with a non-conducting material.

Class VI. *Non-Air-Heating: Wallsend Coal.*—The 'Miser' heating-stove, by Yates, Haywood & Co., is the most efficient in the section in which it is placed; but it made comparatively much smoke. The same class of stove, as exhibited by Steel & Garland, had four pillars, whilst the 'Miser' of Yates, Haywood & Co. had only two pillars. Yet it did not prove so efficient as the simpler stove was; but it made less smoke. J. Cornforth's 'Little Wonder' stove was one of the most efficient, as well as the most successful in consuming smoke. It must be explained that the stove was placed in the middle of the room, and was fitted with a 5 inch flue-pipe, 14 feet long, by which the heating surface was more than doubled in area. The duty, according to the results of the test, was at the rate of 9·04° F. rise of temperature per pound of coal consumed per hour; but, allowing off one-third of this as effected by the flue-pipe, leaving an efficiency of 6° F. per pound of coal, the 'Little Wonder' would range in efficiency with the 'Miser' stove. The combustion was good, and resulted from the complete mixture of heated air from the hollow fire-bars with the gases passing over the bridge. The 'Star' heating-stove, by J. Dunnachie, was efficient, and at the same time showed but little smoke. The 'Armstead-Gregory' stove, of R. W. Crosthwaite, was almost entirely smokeless, and was efficient to a medium degree: an unusually large proportion of the heat was carried off up the chimney. The 'Sunlight' stove was but moderately efficient. There was too little radiating and warming surface; moreover, the degree of smoke was very great, for want of adequate provision for the mixture of gases and air. C. B. Gregory's smoke-burning furnace was perfect as a fuel-burner and smoke-preventer, obviously because of two things:—that the combustible gases were kept hot until they were consumed, and that the air for their combustion was heated, and was delivered at the throat of the furnace, so as to meet the hot gases and immediately mix with and inflame them. The efficiency, as it happened, was the minimum, but a large proportion of the heat of combustion was passed away by the chimney. It may be explained that this particular furnace was not specially adapted for heating an apartment, but for operations on a much larger scale than this function. Jobson's 'Gill' stove, by the Derwent Foundry Company, happens to have been the least efficient of the section in which it is placed. It is distinguished by a direct downward draught. The smoke is of a medium shade.

Class VI. *Non-Air-Heating: Anthracite.*—The 'Economy' portable stove, and the 'Crown Jewel' stove, of Harry Hunt, proved of the highest efficiency in this section. The 'Armstead' stove, by R. W. Crosthwaite, designed on the principle of detaining and circulating the hot gaseous products at the upper part of the stove, worked with a considerable degree of efficiency. Next come the 'Albion' stove, of Brown & Green, which shows considerable efficiency; and, lastly, the 'Economy' base-burner, by Harry Hunt.

Class VI. *Slow-Combustion Tests for Long Periods.*—The best developed stove for heating air—Mr. Lönholdt's—has clearly made the best performance.

THE MOST REMARKABLE RESULTS OF PERFORMANCE.

The most prominent results of the tests of grates and stoves are given in the following Table. The first and second places in efficiency are occupied by the close

Table XIX.—THE MOST REMARKABLE RESULTS OF PERFORMANCE.

IN THE ORDER OF EFFICIENCY			
Class	Exhibitor and open grate	Walls-end or anthracite	Rise of temp. per lb. of coal.
No.			deg. F.
4	H. E. Hoole. Reflector	W.	6·33
1	T. Potter & Sons. Thermhydric	W.	5·16
5	T. E. Parker. Vencedor	W.	5·06
5	M. Feetham & Co. Hurst grate	A.	5·03
3	W. S. Melville. Shovel, under-feed	W.	4·93
3	E. R. Hollands. Under-feed	W.	4·90
1	Barnard & Co. Anthracite grate	A.	4·90
3	E. H. Shorland (G. L. Shorland's patent). Under-shovel	W.	4·71
5	Steel & Garland. Kensington	W.	4·58
5	The Coalbrookdale Company. Kyrle	A.	4·53
5	T. Feetham & Co. Hurst grate	W.	4·22
2	Barnard & Co. Glow-fire.	W.	4·00
2	J. B. Petter. Nautilus	W.	3·93
2	Doulton & Co. Tile grate	W.	3·78
5	W. I. Henry. Smoke-purifyer	W.	3·16
3	Brown & Green. Under-feed	W.	2·85
	Close stoves		
6	F. Lönholdt	A.	11·51
6	W. Stobbs	A.	11·33
6	H. Hunt. Economy Portable	A.	8·11
6	Yates, Haywood & Co. Miser	W.	6·80
6	H. Hunt. Crown Jewel	A.	6·66
6	J. Cornforth. Little Wonder	W.	6·00
6	H. J. Newcome	W.	4·80
6	R. W. Crosthwaite. Gregory	W.	3·76

IN THE ORDER OF SMOKE-PREVENTION			
Class	Exhibitor and open grate	Walls-end or anthracite	Smoke-shade
No.			deg. F.
5	W. I. Henry. Smoke-purifyer	W.	0·91
2	Doulton & Co. Tile grate	W.	1·33
5	T. Feetham & Co. Hurst grate	W.	1·41
3	Brown & Green. Under-feed	W.	2·12
5	T. E. Parker. Vencedor	W.	2·28
2	Barnard & Co. Glow-fire.	W.	2·36
3	E. R. Hollands. Under-feed	W.	2·52
4	H. E. Hoole. Reflector	W.	2·55
2	J. B. Petter. Nautilus	W.	2·81
3	E. H. Shorland. Under-shovel	W.	3·00
1	T. Potter & Sons. Thermhydric	W.	3·50
5	Steel & Garland. Kensington	W.	3·66
3	W. S. Melville. Shovel, under-feed	W.	4·14
	Close stoves.		
6	R. W. Crosthwaite. Gregory	W.	0·46
6	J. Cornforth. Little Wonder	W.	0·69
6	H. J. Newcome	W.	2·00
6	Yates, Haywood & Co. Miser	W.	4·48

stoves of F. Lönholdt and W. Stobbs, with which, burning anthracite, the temperature of the room was raised upwards of 11° F. per pound of coal consumed per hour. The first and second places for lowest smoke-shade are taken by the close stoves of R. W. Crosthwaite ('Armstead-Gregory' Stove) and J. Cornforth.

Of the open grates, that of H. E. Hoole stands first for efficiency—a remarkable testimony to the value of good and well-placed heat-reflecting surface. The next is T. Potter & Sons', whose thermhydric grate or stove is a testimony to the value of fully developed air-heating and radiating surface. Then T. E. Parker shows the value of a downward back-angle draught, and M. Feetham & Co. prove also the efficiency of downward draught. Next are W. A. Melville and E. R. Hollands, also E. H. Shorland, who prove the merit of under-feeding and an upward through draught; although, on the contrary, Brown & Green, who also under-feed, stand at the foot of the list. This inferiority of position may probably be accounted for by the narrowness of the base of the fire—which is contracted by the insertion of a sloping back—and a deficiency of radiating power.

In the order of smokelessness, W. I. Henry's back filter-bed or smoke-purifyer, of iron-turnings, through which the draught is conducted from the back of the fire, takes the first place; and yet it is nearly the lowest in the list for efficiency. Doulton's tile grate, too, next to W. I. Henry's grate for smokelessness, stands next to it also for low efficiency.

GENERAL OBSERVATIONS ON THE RESULTS OF THE TESTS.

It is worthy of observation that even the densest smoke-shades that have been recorded, in the tests of grates and stoves, are light comparatively, when the smoke of industrial establishments and of steam-boilers is taken iuto consideration. The reasons are not far to seek, since the smoke of open grates is excessively diluted with air, and that of close stoves also, though in a less degree. Such preliminary dilution, of course, makes no difference in the final condition of the atmosphere, whilst it may divert attention from the magnitude and importance of the evil.

It has been demonstrated that in close stoves the combustion of smoke-making fuel is much more nearly complete than in any kind of open grates, and that the average smoke-shade is decidedly lighter than in any kind of open grates; that the dilution of the gaseous products of combustion is much less in close stoves than in open grates; and that, partly in consequence of this favourable condition, and partly in consequence of the greater freedom for parting with heat by radiation, as well as by conduction, close stoves are much more efficient for warming rooms, and more economical of fuel, than open grates. But whilst the close stoves raise the temperature one-half more than the open grates, these, on the contrary, radiate locally at double the intensity of the radiation from those; these also exhibit a degree of life and brightness unknown to those; and, wasteful of heat though they are, it is likely that the open grates will continue to be the principal generators of heat from solid fuel.

Of the open grates, those are the most effective, as well as the least smoke-making, in which the distilled gases are caused to pass through the incandescent fuel, and so to become sufficiently heated in combinatiou with air also passed through the fuel, as to be consumed more or less perfectly, to an extent at least which is not attained in other grates of direct open draught.

Anthracite, as a fuel, appears from the general results of testing to be as efficient as Wallsend coal in open grates, whilst it is decidedly more efficient in close stoves. It is also remarkably more efficient in grates and stoves in which a supply of warmed fresh air is provided and delivered into the room. Such a function does not appear to be fulfilled economically with Wallsend coal as fuel. On the contrary, grates and stoves burning bituminous coal appear to do better for heating efficiency, when left to operate by simple radiation and conduction; with the exception of the most wasteful kinds of grate—those of Class I.—having bottom grids and a direct upward draught. For such grates the air-warming appliances are promotive of economy.

The diffusion of heat throughout a room appears to be accomplished in the course of ordinary circulation, with plain grates, as effectively as with ventilating grates. The difference is very considerable between the temperatures of the lowermost and the uppermost strata of air in the room. It remains a question whether, in rooms of ordinary proportions and finish, the temperature may not be more nearly equalised than it was proved to be in the testing houses; and it is in evidence that temperatures not varying by more than 2° F. were attained in an apartment partly warmed by air discharged from the grate.

With respect to the distribution of the heat of combustion of fuel in an apartment, it has been shown that though a large proportion of heat is carried off in the chimney, an equally large proportion is absorbed by the walls: in the case of close stoves, more than one-half of all the heat. The bearing of this conclusion on the construction of houses, leads to the deduction that comparatively thick walls are conducive to uniformity of internal temperature—to the prevention of excessively high temperature in the summer months, and of excessively low temperature in winter. That great thickness of walls is preventive of great extremes of temperature, is a practical conclusion which has generally been accepted. Comparatively thin walls, or shells, on the contrary, give rise to extremes of temperature. It has now been demonstrated that the walls of a room act as equalising heat-reservoirs, heat being absorbed by the walls when the interior temperature rises, and emitted by them and absorbed by the air of the room when the interior temperature falls.

In the Table (XIX.) of the most remarkable results of performance, there are instructive and suggestive contrasts which would bear further investigation, and from which useful practical deductions may be anticipated.

D. K. CLARK.

ADDENDUM.

Independently of the results of the special tests above investigated, observations were made of the smoke-shades that proceeded from the chimneys of grates and stoves in their places in the Exhibition whilst in daily action. The temperatures of the gases in the chimneys were also noted. The following are the averaged results of observations made during four consecutive days in January 1882, on the smoke-shades and temperatures of twenty-six open grates and three close stoves burning Wallsend coal. In parallel columns are given the respective smoke-shades, and temperatures in the chimney, observed during the special tests:—

Class	Observed in the Exhibition building		Observed during the special tests in the testing houses	
	Average smoke-shade	Average temperature in the chimney	Average smoke-shade	Average temperature in the chimney
No.		Fahr.		Fahr.
1	4·50	202°	3·23	175·7°
2	3·30	169	3·66	211·2
3	3·50	174	2·55	136·1
4	4·50	217	2·75	210·2
5	5·30	225	2·53	376·0
Average of Nos. 1–5	4·20	197	2·94	222
No. 6	2·50	199	2·53	—

Here it is shown that the smoke-shades are much darker under the ordinary attention given to the open grates in the daily routine of the Exhibition, than under the better management with which the special tests were conducted. For the close stoves, which were less dependent on skilled management, the smoke-shades are identical. The temperatures in the chimney fluctuate in a manner to be expected under the circumstances. For the open grates they range lower in the Exhibition building than in the testing houses—a variation readily accounted for by the comparatively exposed situation of the chimneys in the Exhibition building, and their being constructed of sheet-iron.—D. K. C.

II. REPORT ON TESTS OF COAL-BURNING KITCHENERS, &c., 1882.

TWENTY-SEVEN complete tests of kitcheners and ranges were made for roasting meat and baking puff pastry, comprising nineteen different exhibits, under the supervision of Mrs. Charles Clarke, Lady Superintendent of the National Training School of Cookery, South Kensington, who kindly volunteered to assist at the tests. The fuel consumed was, for the most part, hard steam coal. The results are given in the annexed Table (XX.), in which also the dimensions of the roasters are given.

No. 1. THE WILSON ENGINEERING COMPANY.—Portable range, 4 feet wide, not requiring any brick-setting. The fire is in the middle, between two ovens. The fire door is perforated, for the admission of air above the fire; it is made double and hollow, so that the air passing between the plates becomes heated before reaching the fire. Air is also admitted from below the fire, up the outer sides of the furnace, which is of cast-iron, between gills, to meet the gases from the furnace, the air being heated as it rises. The intermixture is promoted at the point of meeting by a baffle-plate. The products of combustion pass over the oven down the outer side, and under the bottom. The bottom is gilled, in order to better abstract the heat of the gases. The boiler, at the back, is made of steel and wrought iron, and can hold 10 gallons of water. It does not form part of the furnace. The bottom of the range is enclosed, so that the heat is retained there. (Plate 29.)

No. 2. M. FEETHAM & Co.—W. F. S. kitchener, built into brickwork. The fire is supported by a rack-and-pinion motion, by means of which it may be raised or lowered as desired. The foul gases from the roaster and the oven are drawn down from the upper part and passed through the fire.

No. 3. JOHN M. STANLEY.—The novel feature of this range is the combination of the principles of open and of closed fire-places. The fire-back is closed, and forms a retort or hopper, into which the fresh fuel is delivered, and where the gases are distilled. The gases are passed through the fire and are so consumed. The products pass out through the sides and the back at the lower part, and thence pass under the ovens, up the outer sides, and over the top, to the flue. (Plate 30.)

No. 4. M. FEETHAM & Co.—Sayer's Dust-Consuming Range, containing two ovens and two hot-closets.

No. 5. T. J. CONSTANTINE.—The 'Treasure' Range, No. 88. The furnace or fire-pot is of cast-iron; the sides and the back are hollow, forming air-spaces. The middle fire-bar is hollow, into which air is admitted from the ashpit. This air passes all round three sides of the fire-pot, and passes into it through slots at the top of the three sides, where it meets and consumes the smoke which rises from the fire. The fire-bars are feather-edged at the lower side to facilitate draught. The door is triple-chambered, or so divided by diaphragms as to heat the air that is admitted into it from the front, through holes at the lower part: the air being passed upwards, then downwards, and then upwards, before entering the furnace through slots at the upper part. The

passages through the door are subdivided by gills. The gaseous products pass over the top and down the outer side of each oven. (Plate 30.)

No. 6. C. Churchill & Co.—The 'Greene' Soft-Coal Cooking-Stove. The furnace is made with firebrick sides and a sloping firebrick back. The grates consist of bars with numerous perforations; across the upper part of the furnace, and facing the inclined back, air in small jets is delivered upwards from a cast-iron air-duct towards the sloping back, to meet and consume the smoke. The gases pass away over the far end of the oven, which is below the furnace, then down through two flues at the back of the oven and under the floor of the oven on each side, and back under the floor into the middle. (Plate 31.)

No. 7. W. Stobbs.—'Beebe' Kitchen Range, burning anthracite. It is set in firebrick, the sides of the fire are inclined towards each other backwards, and the sides of the ovens, one on each side of the fire, widen backwards correspondingly. (Plate 33.)

No. 8. Newton, Chambers & Co.—The 'Thorncliffe' Range has two baking and roasting ovens, and two hot-closets below. Between these the fire is placed, formed with two thick firebricks, one next each closet. The flame passes over each closet, then under the oven above it, and then over to the flue. There is the speciality that the way out from the ovens is by an independent exit direct into the outer flue; so that the ventilation of the oven is not liable to be interrupted by the regular draught of the range. (Plate 31.)

No. 9. The Eagle Range and Foundry Company.—The 'Eagle' Range. The front bars are upright, the grate is hinged at the back, and is movable up and down at the front, so as to increase or diminish the body of fire. It is let down for roasting; lifted for baking in the oven or for boiling. The flame passes over the top of the oven and down the outer side, and thence to the flues behind. (Plate 32.)

No. 10. A. C. Engert.—The speciality consists in the mode of feeding the fire from the coaling-box at the back, in which fresh coal is deposited. The box is moved forward as required by means of a lever.

No. 11. Rosser & Russell.—The fire is of such a size that meat can also be roasted in front. With the object of preventing an excessive consumption of fuel, and to keep the hot-plate and ovens heated by a small fire, the fire-place is fitted with a rising bottom, movable vertically by a rack-and-pinion motion, which can be raised as the fuel burns away.

No. 12. W. Stobbs.—'Beebe' Range, No. 1, burning anthracite; the same as in No. 7.

No. 13. J. M. Stanley.—The same as No. 3.

No. 14. M. Feetham & Co.—W. F. S. Kitchener; the same as No. 2.

No. 15. The Radiator Range Company.—'Radiator' Range. The fire-place is circular, and projects to the extent of a half-circle beyond the front of the range. The gases pass through a narrow opening horizontally into a combustion-chamber at the back, for the consumption of smoke, whence they pass over and under the ovens, one on each side. By the projection of the fire-place, places are provided for three joints roasting at once, in addition to the roasting ovens; and the ovens are not exposed to the direct heat of the fire. (Plate 33.)

No. 16. M. Feetham & Co.—Sayer's Dust-consuming Range; the same as No. 4.

No. 17. The Wilson Engineering Company.—The same as No. 1.

TABLE XX.—RESULTS OF TESTS OF

No. of test	Date of test	Names of exhibitors	Description of kitchener	Dimensions of Roaster: Height	Dimensions of Roaster: Depth	Dimensions of Roaster: Width	Heating up of Roaster: Time heating up	Heating up of Roaster: Temperature	Joint: Time roasting	Joint: Description of joint	Joint: Weight of joint on	Joint: Weight of joint off
1	2	3	4	5	6	7	8	9	10	11	12	13
No.	1882			in.	in.	in.	min.	deg. F.	h. m.		lb. oz.	lb. oz.
1	Feb. 6	The Wilson Engineering Company	Portable Range, 4 feet wide	15	22	14	55	250°	0 55	Leg of mutton	5 12	4 14
2	„ 6	M. Feetham & Co.	Feetham's W.F.S. Kitchener, 5 feet wide	18	19½	15¼	73	250	1 17	Do.	5 1	4 0
3	„ 6	J. M. Stanley	Hopper-fed Cooking-Range	18	21	18	45	250	1 3	Do.	5 4	4 9
4	„ 6	M. Feetham & Co.	Sayer's Dust-consuming Kitchen Range	10½	17	15	30	260	0 50	Do.	4 11	4 1
5	„ 7	T. J. Constantine	The Treasure Range, 4 feet wide	17	23	14½	40	250	1 33	Sirloin of beef	12 9	10 13
6	„ 7	C. Churchill & Co.	The Greene Soft-coal Cooking-Stove	13½	20	19	40	250	1 37	Do.	11 14	9 5
7	„ 8	W. Stobbs	Beebe Kitchen Range, 4½ feet wide	10	20	12	31	250	1 44	Do.	12 4	8 13
8	„ 8	Newton, Chambers & Co.	The Thorncliffe Range, 4 ovens	15	20¼	18	30	250	2 0	Do.	12 6	10 1
9	„ 8	The Eagle Range & Foundry Co.	Eagle Range, 4 feet wide	20	16½	14½	40	260	1 55	Do.	12 14	10 12
10	„ 12	A. C. Engert	Back Coking-box Range, 4 ft. 6 in. by 2 ft. 8 in. high × 2 ft. 2 in. deep	18	22	18	65	260	2 30	Do.	12 13	9 7
11	„ 12	Rosser & Russell	8 feet wide	18	16	28	50	260	2 20	Do.	12 0	9 11
12	„ 12	W. Stobbs	Beebe Kitchen Range, 4½ feet wide	10	20	12	57	250	2 0	Do.	13 8	10 6
13	„ 13	J. M. Stanley	Hopper-fed Cooking-Range	18	21	18	65	250	2 30	Do.	12 7	8 4
14	„ 13	M. Feetham & Co.	Feetham's W.F.S. kitchener, 5 feet wide	18	19½	15½	27	250	2 23	Do.	12 6	8 1
15	„ 13	The Radiator Range Co.	Radiator Range, 4½ feet wide	17½	20	17	56	250	2 39	Do.	11 10	9 3
16	„ 15	M. Feetham & Co.	Sayer's Dust-consuming Kitchen Range	10½	17	15	65	260	2 30	Do.	11 10	8 8
17	„ 15	The Wilson Engineering Company	Portable Range, 4 feet wide	15	22	24	40	250	2 30	Do.	12 2	8 5
18	„ 15	The Sunlight Stove Co.	Dutch Oven, 2½ feet wide	9¼	11¼	14½	42	250	2 35	Do.	12 2	9 6
19	„ 16	Brown & Green	Smoke-consuming Kitchener, 4½ feet wide	16	18¼	20	45	250	2 35	Do.	12 5	8 13
20	„ 16	Do. do.	Gem Stove, 2 feet wide	10	13	13	75	250	2 30	Do.	11 2	9 8
21	„ 23	Do. do.	The Times Portable Cooking-Stove, 4 feet wide	13	16½	16½	25	250	2 7	Do.	12 7	8 15
22	„ 27	J. Court	3½ ft. wide, 16 in. deep	14	15	14	40	250	3 0	Do.	12 3	9 15
23	„ 25	The Falkirk Iron Company	The Falkirk Smokeless Close-fire Kitchener, 4 feet wide	14½	15	15	105	250	2 30	Do.	11 5	9 2
24	„ 25	Do. do.	The Auxiliary	—	—	—	50	250	2 0	Do.	11 3	8 2
25	„ 28	Do. do.	The Falkirk Smokeless Close-fire Kitchener: Left oven	14½	15	15	47	250	2 30 [1]	Do.	12 0	10 2
			Right oven	14	15	13	—	—	2 45 [2]	Do.	12 0	10 1
			In front	—	—	—	—	—	2 15 [3]	Do.	12 0	8 12
26	Mar. 13	The Radiator Range Company	Radiator Range, 4½ feet wide	—	—	—	63	320	2 42	Do.	11 7	9 [illegible]
27	„ 23	T. J. Constantine	No. 88, 4 feet Range	17	23	14½	38	250	2 02	Do.	12 3	8 15

[1] Joint in right oven. [2] Joint in left oven. [3] Joint in front.

COAL-BURNING KITCHENERS, 1882.

No of test	Joint—*continued.* Weight after roasting: Dripping	Total	Loss of weight		Puff Pastry: Time in oven	Temperature: On	Off	Coal Consumed: Wood	Hard steam coal	Ash	Per cent.	Smoke shade	Quality of the Work done: Joint	Pastry	Raising Water to Boiling Point in Copper Standard Pan: Initial temperature	Boiling point	Rise of temperature	Weight of water	Time required
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
No	lb. oz.	lb. oz.	lb. oz.	p. ct.	min.	d. F.	d. F.	oz.	lb. oz.	oz.	per ct.	No.			deg. F.	deg. F.	deg. F.	lbs.	min.
1	0 6	5 4	0 8	8·69	10	380°	400°	—	15 0	5	2·08	4·18	—	—	48°	212°	164°	5	6
2	0 8	4 8	0 9	11·11	—	—	—	24	20 4	12	3·70	3·67	—	—	60	140	80	—	—
3	0 5	4 14	0 6	7·14	15	320	380	32	30 15	15	3·03	3·85	—	—	—	212	—	5	12
4	0 4	4 5	0 6	8·0	7	320	410	—	17[1] 4	10	3·62	2·60	—	—	—	—	—	—	—
5	0 10	11 7	1 2	8·95	11	340	400	32	12 4	2	1·02	2·27	Very well done	Well done	50	212	162	10	11
6	1 8	10 13	1 1	8·95	12	340	380	24	15 6	4	1·63	2·42	Well done	Very well done	52	212	160	10	25
7	2 4	11 1	1 3	9·69	19	290	380	32	16 11	10	3·75	2·82	Very well done	Well done	52	212	160	10	24
8	1 4	11 5	1 1	8·58	24	280	330	32	21 7	3	0·87	2·91	Do.	Fair	52	212	160	10	15
9	0 12	11 8	1 6	10·68	30	300	370	24	13 0	23	11·06	2·92	Well done	Very well done	66	212	152	10	20
10	1 6	10 13	2 0	15·61	10	320	400	32	24 10	8	2·03	1·33	Do.	Fair	64	212	166	10	30
11	1 4	10 15	1 1	8·85	15	310	380	32	20 0	11	3·44	3·0	Do.	Do.	46	212	166	10	26
12	1 11	12 1	1 7	10·65	12	380	380	32	Anthr. 17 4	27	9·78	0·33	Do.	Well done	46	212	166	10	28
13	2 9	10 13	1 10	13·07	10	310	320	32	Hd. st. 33 15	27	4·97	2·64	Do.	Fair	51	212	161	10	45
14	2 3	10 4	2 2	17·17	10	310	320	24	19[2] 0	10	3·29	3·25	Fairly done	Do.	51	212	161	10	17
15	1 5	10 8	1 2	9·68	12	380	400	24	16 0	5	1·95	2·80	Well done	Well done	50	212	162	10	30
16	1 8	10 0	1 10	13·98	13	300	310	32	20 12	12	3·61	3·62	Do.	Do.	52	212	160	10	40
17	1 15	10 4	1 14	15·47	12	310	320	16	14 6	10	4·35	3·64	Do.	Do.	52	212	160	10	35
18	1 5	10 11	1 7	11·86	20	310	310	16	22 11	10	2·75	2·50	Do.	Fair	50	212	162	10	40
19	1 11	10 8	1 13	14·72	17	310	380	32	18 9	10	3·37	1·60	Very well done; in front, well done	—	48	212	164	10	25
20	0 9	10 1	1 1	9·55	10	310	410	24	Anthr. 7 4	10	8·62	0·50	Well done	—	50	212	162	10	35
21	2 3	11 2	1 5	10·55	10	320	410	32	Anthr. 15 0	44	18·33	0·67	Do.	-	50	212	162	10	23
22	1 2	11 1	1 2	9·23	15	280	300	24	Hd. st. 14 8	37	15·95	2·72	Underdone	--	56	212	156	10	87
23	0 13	9 15	1 6	12·15	15	280	320	Coke, 11 lbs. Gas 51 c.ft.		32	16·33	—	Well done	—	48	212	164	10	17
24	1 12	9 14	1 5	11·71	10	300	410	Coke, 6·9 lbs. Gas 20 c.ft.		—	—	—	Do.	—	48	212	164	10	24
25	1 2	11 4	0 12	6·25	10	400	400	—		—	—	—	Do.	--	50	212	162	10	55
	0 9	10 10	1 6	11·46	—	—	—	Coke, 20·9 lbs. Gas 28 c.ft.		30	9·26	—	Do.	—	—	—	—	—	--
	1 10	10 6	1 10	13·52	—	—	—	—		—	—	—	Very well done	—	—	—	—	—	—
26	0 13	10 2	1 5	11·47	12	300	340	Wood 24	Hd. st. 13 5	10	4·69	2·25	Do.	—	50	212	162	10	28
27	1 12	10 11	1 8	12·31	—	—	—	24	13 5½	9	4·22	—	Do.	—	50	212	162	10	14

[1] Half anthracite and half hard steam cinders.

[2] Hard steam coal, 14 lbs.; Welsh steam dust, 7 lbs.; cinders, 14 lbs. 8 oz.; } at starting.

No. 18. THE SUNLIGHT STOVE COMPANY.—Dutch Oven. The fire-place is above the oven. Air is admitted through grates all round the fire-place, to perfect the combustion. The draught from the fire descends on both sides of the oven, reuniting at the bottom, and proceeding thence to the chimney. There is no boiler, but there is a coil of pipe within the fire-place surrounding the fire. The ends of the pipe rise to the cistern above. (Plate 33.)

No. 19. BROWN & GREEN.—Smoke-consuming Kitchener. The chief speciality is the means of supplying fresh fuel, which is placed in a small trough or tray in front at the bottom of the fire-place, and is pushed in underneath the incandescent fuel by means of a hoe-shaped or flat-faced feeder. Thus the gases distilled from the fresh coal pass upwards through the live coal and are, to a great extent at least, consumed. This range is adapted for cooking in front of the fire as well as in the oven. (Plate 34.)

No. 20. BROWN & GREEN.—The 'Gem' Portable Cooking-Stove. The fire-place and the single oven are side by side. The flue passes over the oven direct to the chimney. The sides, back, and bottom of the stove are cased in an air-jacket. The side of the oven next to the fire is protected by a cast-iron plate, which is kneed so as to pass into the lower air-jacket, under the bottom of the oven. By conduction, the plate assists in heating the oven. For the larger sizes, the flue is carried entirely round the oven. (Plate 35.)

No. 21. BROWN & GREEN.—The 'Times' Portable Cooking-Stove, to burn anthracite. The front of the fire is made in three parts; to slide in and out: the lowest part being upright bars, the middle part a plain plate, and the upper part the feeding door. The grate at the bottom is sloped, being higher at the back than at the front. The area for air passage is thus augmented as compared with a horizontal grate, and the fuel is thrown forward to the front as it is consumed. The middle plate becomes very hot, and is available, in conjunction with the lower bars, for roasting in front. (Plate 35.)

No. 22. J. COURT.—All the air for feeding the fire comes from the roof of the range, entering a long narrow opening there, passing down a pipe at the back to the ash-pit, whence it passes, warmed, up through the fire. The front of the range is thus ventilated, drawing off the fumes and vapours which rise to the upper part. The oven is supplied with heated air for ventilation. The air for this purpose is taken into the narrow space between the fire-place and the oven, passing up one side of a partition, and down the other side, and into the oven at the lower part, whence it passes off at the upper corner to the flue. There is a cast-iron boiler at the other side. (Plate 36.)

No. 23. THE FALKIRK IRON COMPANY.—The 'Falkirk' Smokeless Close-fire Kitchener. The range is heated on a modification of Dr. Siemens' system with coke and gas. The fire-place is backed with a firebrick slab. The bottom grid reaches all the way from back to front, and consists of a series of very deep gills, between which, being hot, the ascending currents of air are heated before entering into combustion. The gas jets are placed in a row, in front, at the level of the grate, and they are directed inwards, at an angle of 45°, into the body of the coke. (Plate 36.)

No. 24. THE FALKIRK IRON COMPANY.—The 'Auxiliary' Cooking-Stove, heated on Dr. Siemens' system, as in No. 23.

No. 25. THE FALKIRK IRON COMPANY.—The 'Falkirk' Smokeless Close-fire Kitchener, as in No. 23.

No. 26. THE RADIATOR RANGE COMPANY.—The same as in No. 15.

No. 27 T. J CONSTANTINE.—The same as in No. 5.

No. 28. J. & J. McMillan.—Ordinary Range. The speciality is a means of under-feeding by means of a square box, having a movable floor, and pivoted at the lower part, on which it is swung outwards to be filled with coal. When filled, it is replaced under the fire-place, and the fresh fuel is pushed up under the live coal; the combustible gases passing through it to be consumed. (Plate 36.)

OBSERVATIONS ON THE RESULTS OF THE TESTS.

The conditions of the Kitcheners varied considerably, with regard to dimensions, as well as to capacity. Those which were most economical in fuel were amongst the largest. In respect of smoke-prevention, A. C. Engert's Kitchener, in test No. 10, made the lowest smoke-shade with bituminous (hard steam) coal. Next comes Brown & Green's Kitchener, No. 19. In No. 10, the coal was gradually distilled, and fed from the back; in No. 19 it was under-fed; and the minimum of smoke in these instances is readily accounted for, on the principles already explained in the Report on Open Grates and Close Stoves. T. J. Constantine's Kitchener, Nos. 5 and 27, the Wilson Engineering Company's, No. 17, and the 'Radiator' Range, No. 26, used the smallest quantities of fuel, in virtue of their superior utilisation of heat. The excellent performance of the Falkirk Iron Company's Kitcheners, burning coke with gas, is due, no doubt, to the employment of gills of great depth as fire-bars, and the preliminary heating of the air and the gas brought into combustion, on Dr. Siemens' principles.

J. & J. McMillan's Kitchener was tested chiefly for smoke-prevention. The smoke-shade averaged 2·20; the temperature was taken at a distance of 6 inches from the front of the fire, and it averaged 217° F.

D. K. CLARK.

III. REPORT ON TESTS OF GAS HEATING-STOVES AND GAS FIRES, 1882.

THIRTY-ONE tests were made of gas heating-stoves, gas fires, and gas water-heaters. The gas was supplied by the Gas-Light and Coke Company. The results of the tests are given in the Table annexed, in chronological order.

The gas heating-apparatus that was tested may be classed as follows :—

1. CLOSE GAS STOVES, traversed by currents of air which are heated by conduction, the gas burning in separate chambers.

2. OPEN GAS STOVES, or COMBINATION FIRES, in which gas is burned in mixture with asbestos, coke, or anthracite.

3. GAS BASKETS, or GAS FIRES, in which gas is burned alone, the heat being delivered by direct radiation, or by reflection.

The results of the tests are given in Table XXI.

1. *CLOSE GAS STOVES.*

No. 1. J. C. STARK & Co.—Cox's Ventilating Gas Stove. It consists of a vertical cylinder covered with a non-conducting substance, heated by luminous jets of gas, burning at the lower part, the fumes ascending into the interior, and escaping at the back of the lower part. Fresh air from without is introduced at the lower part, separated from the gaseous fumes, and ascends and is heated in vertical tubes, from which it is collected in a perforated chamber at the top, whence it is discharged into the room. (Plate 38.)

No. 2. THE SANITARY AND ECONOMIC SUPPLY ASSOCIATION.—Dr. Bond's 'Euthermic' Ventilating Gas Stove (Pattern B). It consists of four concentric vertical cylinders, forming a central cylindrical chamber, and three annular spaces. Air from the room is admitted into the central chamber and the second annular chamber at the lower end, and ascends to the top, whence it escapes heated into the room. A ring-burner of atmospheric gas, on a swinging bracket, is placed at the lower end of the first annular chamber, the hot gaseous products ascending to the top, then descending by the outer annular chamber to the lower part, whence they pass off by flue. The air passing through the stove becomes heated by conduction through the intervening cylinders. The outermost cylinder, or the casing, is corrugated in order to augment the external surface for radiation and conduction. (Plate 38.)

No. 3. SANITARY AND ECONOMIC SUPPLY ASSOCIATION.—Dr. Bond's Gas Stove (Pattern A). Within an upright corrugated metal cylinder an inverted cone is fixed, into which fresh air is admitted at the lower and smaller end. The air ascends to the top and is thence discharged into the room. Heat is supplied from an annular burner of atmospheric gas at the lower end, surrounding the inverted cone. The hot products rise and fill the casing, surrounding the cone. They descend from the top through a number of tubes outside the casing, from the lower end of which they pass away into a flue.

The air in ascending within the inverted cone becomes heated, whilst heat is also given off from the casing by radiation and conduction. (Plate 37.)

No. 4. Wm. Harvie & Co.—Dr. Adams' Gas Stove. An upright cylindrical stove, consisting of four concentric cylinders, forming a central chamber and three annular chambers. Gas is burned at the lower end, the gaseous products passing up amongst a number of small hollow cylinders of brick, and heating them to redness. The products of combustion ascend spirally through the second annular chamber, escaping at the upper part into the flue. Fresh air is admitted in two separate currents; one entering the outermost annular chamber at the bottom and ascending to the top, whence it is discharged; the other entering the outlet chamber at the top, descending to the lower end, turning into and ascending through the first annular chamber, and also escaping at the upper end. In this manner, the ascending current of hot gases heats the two annular columns of air between which it passes. (Plate 38.)

No. 5. G. J. Cox.—Cox's 'Regenerator' Air-warming and Ventilating Gas Stove. An upright cylindrical stove, comprising three concentric cylinders. At the base of the first cylinder a ring Bunsen-burner is in action, the hot gases from which ascend into a chamber at the upper part, whence they descend through the outer annular space, escaping near the bottom. The ascent of the gases is partially arrested and compelled to take a zigzag course by horizontal partitions in the central chamber. Fresh air is admitted into the inner annular space, in which it becomes heated, as it ascends, being exposed to heat from the central chamber and from the outer annular space.

No. 12. Strode & Co.—Schönheyder's 'Sanitary' Stove, for lighting, heating, and ventilating. An upright cylinder, upon the outside of which there are two argand gas-burners. The gaseous products are taken inside the column, and pass down through two pipes inside the casing, whence they pass up through two other pipes, from the upper end of which they pass to the chimney. Fresh air enters at the bottom from the outside, and passes upwards around the four pipes containing the products of combustion. It is discharged into the room at the upper part. Vitiated air is carried off in winter through an opening near the floor; in summer, from the upper part of the room, by an adjustment of valves. For summer use, the products pass direct to the chimney without traversing the vertical pipes. Those pipes containing the hottest products are made double in order to prevent the scorching of the incoming fresh air. Means are provided for moistening the air. A flat or pilaster form of the stove has recently been introduced for use in sitting-rooms. It can be employed in combination with the ordinary fire-place. (Plate 39.)

No. 16. G. Haller & Co.—Kohlhofer's Hot-Air Gas Stove.—Two rectangular chambers, upper and lower, are connected by five upright pipes. Within a central pipe depending from the upper chamber a circular atmospheric gas-burner is in action. The hot gases rise into the upper chamber, descend through two of the upright pipes into the lower chamber, ascend through the two other pipes to the upper chamber, descend through the fifth pipe into the lower chamber, and pass thence into the flue-pipe. (Plate 40.)

No. 27. Ritchie & Co.—'Lux Calor' Ventilating Stove. One or two hollow columns or tubes, on a hollow base, and supporting a hollow chamber at the top. One or two jets of gas burn near the upper part, from which the gaseous products are conducted into the upper chamber, whence they pass down inside the columns. The products are cooled, and partially condensed, collecting at the bottom, where the remaining gas is passed off behind into the room, as, in the opinion of the exhibitors, there is 'no flue required.' (Plate 41.)

No. 28. J. F. Farwig & Co.—George's Gas 'Calorigen.' An upright cylindrical case, in which a ring-burner, of 12 Bray's No. 0 burners, is in action at the base. The hot gases rise and escape at the upper part into the flue. Air to supply the burner

TABLE XXI.—RESULTS OF TESTS OF

No. of test	No. of testing room	Date of test	Name of exhibitor	Exhibitor's titles, and descriptions
No.		1882		
1	2	Feb. 15	J. C. Stark & Co.	Cox's Ventilating Gas Stove; upright cylinder; luminous jets at bottom
2	4	" 15	Sanitary Association	Dr. Bond's 'Euthermic' Ventilating Gas Stove (Pattern B)
3	4	" 16	Do.	Do. Do. (Pattern A)
4	2	" 16	Wm. Harvie & Co.	Dr. Adams' Gas Stove
5	3	" 16	G. J. Cox.	Cox's 'Regenerator' Air-warming and Ventilating Gas Stove
6	2	" 17	Charles Wilson	The 'New Carlton' Gas Heating-Stove
7	2	" 17	Do.	The 'Carlton' Gas Fire
8	5	" 17	Waddell & Main	Dr. Siemens' Gas-and-Coke Fire
9	3	" 17	Do.	Hislop's 'Metallic Gas Fire'
10	2	" 18	J Wright & Co.	Gas-and-Asbestos Stove
11	2	" 20	Pugh Brothers.	Gas-and-Asbestos Fire
12	3	" 20	Strode & Co.	Schönheyder's 'Sanitary' Stove
13	5	" 29	G. Wright & Co.	Dr. Siemens' Gas-and-Coke Fire, with Wright's Bivalve
14	5	" 20	Do.	Gas-and-Anthracite Fire, with Wright's Bivalve
15	5	" 27	Do.	Gas-and-Asbestos Fire, with Wright's Bivalve
16	3	" 21	Haller & Co	Kohlhofer's Hot-air Gas Stoves
17	2	" 22	Billing & Co.	'Sundial' Gas Stove, No. 65½
18	4	" 22	H. and C. Davis & Co.	'Carlyle' Gas Stove, No. 02 (gas and coke)
19	4	" 23	Do.	Gas-and-Asbestos Stove, No. 02.
20	2	" 23	W Sugg & Co.	Gas-and-Coke Stove
21	3	" 23	S. Leoni & Co.	Gas-and-Asbestos Stove
22	3	" 24	Do.	'Perfect' Incandescent Radiator Gas-Fire
23	3	" 25	Do.	Gas-and-Anthracite Stove
24	3	" 27	Do.	Gas Fire, on front
25	4	" 24	G. W. Wigner.	Gas-and-Porous-Clay Fire
26	4	March 2	Do.	Do. (2nd trial)
27	2	Feb. 28	Ritchie & Co.	'Lux Calor' Ventilating Stove
28	4	" 28	J. F. Farwig & Co.	George's Gas 'Calorigen'
				GAS WATER-HEATERS.
29	—	Feb. 16	G. J. Cox.	Instantaneous Water-Heater
30	—	" 23	S. Leoni & Co.	Do. do.
31	—	" 25	G. W. Wigner.	Wigner and Harland's hot-water apparatus: small burner, given quantity of water 21¼ gallons
32	—	" 25	Do.	Wigner and Harland's hot-water apparatus: large burner, given quantity of water 21¼ gallons

GAS HEATING-APPARATUS, 1882.

No. of test	Time under trial	Fuel Consumed: Description	Fuel Consumed: Weight	Fuel Consumed: Ash	Fuel Consumed: Per cent.	Quantity of gas consumed	Temperature: External, average	Temperature: At walls, 6 feet high: At commencement	Temperature: At walls, 6 feet high: Total average	Temperature: At walls, 6 feet high: Average last hour	Temperature: Difference due to radiation, 6 feet from fire, 5 feet high: Total average	Temperature: Difference due to radiation, 6 feet from fire, 5 feet high: Average last hour	Temperature of warmed air delivered into the room
No.	h. m.		lb. oz.	lb. oz.	Per cent.	cub. ft.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
1	4 0	—	—	—	—	57	36°	50°	55·45°	57·67°	0·66°	2·33°	290°
2	4 20	—	—	—	—	48	36	52·25	54·60	56·0	0·40	—	180
3	4 0	—	—	—	—	41	37	45	48·97	50·92	0·66	1·0	132·50
4	4 0	—	—	—	—	61	37	44·25	49·22	51·92	1·55	2·0	307·50
5	4 0	—	—	—	—	44	37	46	50·25	51·75	2·0	2·0	185
6	4 0	—	—	—	—	98	48	49	54·25	56·42	4·80	6·66	—
7	4 0	—	—	—	—	11	48	—	—	—	—	—	—
8	4 0	Coke Anthracite	7 4 6 2	1 2	8 41	25·3	48	48·50	54·65	57·75	11·40	17·67	—
9	4 0	—	—	—	—	120	48	49·25	53·60	55·59	6·80	9·0	—
10	4 0	Asbestos	—	—	—	95	48	51·75	57·10	57·91	3·80	5·0	—
11	4 0	Asbestos	—	—	—	133	39	44·25	48·17	50·59	7·56	10·0	—
12	4 0	—	—	—	—	114	39	44	52·41	56·25	6·0	6·67	130·75
13	5 0	Wood Coke	0 8 9 12	—	—	29	48	48	52·82	55·83	14·18	19·33	—
14	5 0	Anthracite	17 14	2 5	12·94	36·5	39	46·25	51·23	52·33	16·37	10·33	—
15	4 3	Asbestos	—	—	—	220	51	49·50	51·53	52·0	7·78	11·0	—
16	4 0	—	—	—	—	38·5	50	48·50	52·47	54·42	2·11	2·0	—
17	4 0	—	—	—	—	56·5	48	48·75	52·14	53·83	3·0	4·33	—
18	4 0	Coke	1 2	—	—	50	48	50·75	54·52	58·92	5·22	7·67	—
19	4 0	Asbestos	—	—	—	82	45	49·25	53·89	55·25	4·89	6·33	—
20	4 0	Coke	4 1	0 4	6·15	73	45	49·0	52·42	53·25	7·67	8·0	—
21	4 0	Asbestos	—	—	—	149	45	49·25	53·50	55·33	11·0	12·67	—
22	4 0	Coke	4 7	—	—	80	45	47·25	51·89	54·41	10·44	12·34	—
23	4 0	Anthracite	—	0 2	1·67	77	50½	50·25	54·44	56·75	10·44	14·0	—
24	4 0	—	—	—	—	71	51	52·25	56·47	58·75	8·0	11·34	—
25	4 0	Porous clay in balls	4 0	—	—	79	45	48	51·28	52·75	4·34	6·0	—
26	4 0	"	6 6	—	—	108	47	50·25	52·72	54·33	4·44	5·67	—
27	4 0	—	—	—	—	34	46	51	55·67	57·09	3·34	3·67	—
28	4 0	—	—	—	—	70·5	46	50·75	55·11	57·17	0·67	1·67	300
							Initial temperature of water.		Final temperature as delivered	Rise of temperature.	Rate of delivery of water per hour.		
29	0 16	—	—	—	—	10·3	53	—	108	55	45 gals.		
30	0 15	—	—	—	—	13	48	—	110	62	75 "		
31	2 10	—	—	—	—	20	46	—	71	25	—		
32	1 32	—	—	—	—	35	43	—	89	46	—		

is brought into the stove by a pipe from the outside. A separate supply of fresh air is introduced from the outside, in a pipe which is carried into the casing, where it is formed with two coils, and terminates in an opening at the top, through which the heated air passes into the room. (Plate 41.)

2. *OPEN GAS STOVES, OR COMBINATION FIRES.*

No. 8. WADDELL & MAIN.—Dr. Siemens' Gas-and-Coke Fire. The back of the fire-place is covered by a wall-plate of copper, reaching half above the floor-plate of the fire and half below. The floor-plate, or 'dead-plate,' is riveted to the wall-plate, and stops short about an inch from the front bars. Into this interval a $\frac{1}{2}$-inch gas-pipe is laid, drilled with $\frac{1}{16}$-inch holes, $1\frac{1}{2}$ inches apart at the upper side, inclining inwards at an angle of 50° with the vertical. A supply of heated air for combustion is provided by the insertion of a kneed iron plate, under the dead-plate and near the wall-plate, so as to form a kneed channel, 1 inch wide, through which the air ascends at the back, and then passes horizontally to the front, where it meets the jets of gas. The air is heated on its way through the passage thus provided for it, and the heating surface is augmented by the insertion of a corrugated sheet of copper in the vertical part of the passage, subdividing it into channels; so much so that the air, it is said, can be raised to upwards of 600° F. of temperature. The flame and hot products play upon and are dispersed in the body of coke laid upon the dead-plate; the coke is thus ignited and becomes incandescent. After it becomes thoroughly ignited the gas may be turned off. (Plate 42.)

No. 9. WADDELL & MAIN.—Hislop's 'Metallic' Gas Fire. A fireclay hollow backing, in which iron is mixed to give durability, is placed on a solid floor-plate, and is covered with asbestos in pieces. Gas is admitted within the backing, and is discharged through numerous small orifices into the body of asbestos, where it burns, the asbestos being raised to incandescence. (Plate 42.)

No. 10. J. WRIGHT & Co.—Gas-and-Asbestos Stove. A body of asbestos is heated by means of a row of atmospheric gas jets.

No. 11. PUGH BROTHERS.—Gas-and-Asbestos Fire, heated by atmospheric gas jets.

No. 13. G. WRIGHT & Co.—Dr. Siemens' Gas-and-Coke Fire, with Wright's bivalve grate.

No. 14. G. WRIGHT & Co.—Gas-and-Anthracite Fire, on Dr. Siemens' system, with Wright's bivalve grate.

No. 15. G. WRIGHT & Co.—Gas-and-Asbestos Fire, with Wright's bivalve grate.

No. 18. H. & C. DAVIS & Co.—The 'Carlyle' Gas-and-Coke Stove, No. 02, on Dr. Siemens' system.

No. 19. H. & C. DAVIS & Co.—The 'Carlyle' Gas-and-Asbestos Stove, No. 02. Luminous jets of gas.

No. 20. W. SUGG & Co.—Gas-and-Coke Stove.

No. 21. S. LEONI & Co.—Gas-and-Asbestos Stove, adapted to an ordinary grate. A fireclay back is inserted, also a fireclay front tile, behind the bars, a little clear of them. The space between the two tiles is filled with asbestos, which is heated by atmospheric flames introduced from below. A sheet of atmospheric gas is burned against the face of the front tile, which is trimmed with asbestos, and becomes highly heated and radiates heat into the room. (Plate 43.)

No. 22. S. LEONI & Co.—Gas-and-Coke Fire, on the same system as No. 21, except that coke is supplied instead of asbestos.

No. 23. S. LEONI & Co.—Gas-and-Anthracite Fire, on the same system as No. 21, except that anthracite is supplied instead of asbestos.

No. 25. G. W. WIGNER.—Gas-and-Porous-Clay Fire, adapted to an ordinary grate. The clay is rendered porous by having been kneaded with charcoal and then baked, when the charcoal is burned out. A backing of this clay is placed in the grate, and the same material in lumps is filled into the grate.

No. 26. G. W. WIGNER.—Gas-and-Porous-Clay Fire, as in No. 25, having larger burners.

3. *GAS BASKETS, OR GAS FIRES.*

No. 6. CHARLES WILSON.—The New 'Carlton' Gas Heating-Stove. A sqnare nprighl structure of glazed terra-cotta, having an open front. A finely perforated metal plate is inlaid, inclined backwards, to which platinum wire is attached, and which is backed up with a firebrick. An atmospheric gas-burner, placed along the lower edge, heats the plate with its backing; and the heat is radiated into the room. (Plate 43.)

No. 7. CHARLES WILSON.—The 'Carlton' Gas Fire. A perforated iron plate on a backing of firebrick, heated by an atmospheric burner at the lower edge. The apparatus is hung on the front of any grate, and heats the room by radiation. (Plate 43.)

No. 17. BILLING & Co.—The 'Sun-dial' Gas Heating-Stove, No. 65½. A sqnare upright structure, open in front, having a row of luminous jets of gas at the front, along the upper part, the radiated heat of which is reflected from the roof upon a polished metal plate inlaid in an inclined position at the back; from which the heat, together with that which is radiated direct from the gas upon the plate, is reflected into the room.

No. 24. S. LEONI & Co.—'Perfect' Incandescent Radiator Gas Fire. A fire-tile in an iron frame, hnng on the front bars of a grate, trimmed with asbestos on the face, and heated by atmospheric gas from the lower edge. (Plate 43.)

4. *GAS WATER-HEATERS.*

No. 29. G. J. COX.—Instantaneous Water-Heater. A modification of the coil class of heaters. Two coils of tube, right hand and left hand, one within the other, are placed in an upright cylinder, and a third coil surrounds the cylinder. The coils are snrmounted by two shallow cisterns or hollow discs, into which the cold water is delivered, and from which it passes down to and through the coils, from the lower ends of which the water is drawn off by a single outlet. The water is heated by the products of combustion of gas, which ascend the inside of the cylinder, and are conducted downwards on the outside of it in an annular space enclosed by an outer cylinder, after which they pass upwards into the room. The whole is surronnded by a non-conducting casing. The snpply of water is regulated by a tap, from an automatic cistern.

No. 30. S. LEONI.—Instantaneous Water-Heater. An upright cylinder, in which the water is heated by four atmospheric gas-burner tubes, at the base, the hot gases rising through the cylinder and escaping at the top. A narrow annular space is formed by an inner cylinder, into the lower part of which the water to be heated is delivered. The

water overflows at the upper end, and drops on a series of diaphragms, from one to another—towards the centre and the circumference alternately. The heated water is collected at the base, and then run off. (Plate 44.)

No. 31. G. W. WIGNER.—Wigner & Harland's Water-Heater; small burner. The rising pipe is encased in a cylinder of non-conducting material. An atmospheric burner is in action at the lower end, and the hot gases ascending within the casing heat the water as it rises in the pipe.

No. 32. G. W. WIGNER.—Wignér & Harland's Hot-Water Apparatus; large burner. The same as No. 31.

DEDUCTION.

Taking the average result of the twenty-one tests of gas heating-apparatus for rooms, in which gas alone was consumed:—

Average temperature in the room at the commencement . .	47·00° Fahr.
Average rise of temperature during the test	4·10° Fahr.
Average duration of the tests	3·90 hours
Average quantity of gas consumed	82·4 cubic feet
Do. do. per hour	21·13 cubic feet
Rise of temperature per cubic foot of gas consumed per hour .	0°·20 Fahr.
Do. per 10 cubic feet of gas	2° Fahr.

Taking the cost for gas at 3*s*. 6*d*. per 1,000 cubic feet, the cost per 10 cubic feet per hour would amount to 0·42*d*., capable of raising the average temperature 2° Fahr.

To compare the cost of heating by gas with the cost of heating by coal, the average rise of temperature per pound of Wallsend coal consumed per hour was found to be 4°·14; say 2° per half-pound of coal per hour. Allowing 20*s*. per ton as the cost of coal, the cost of half a pound would be 0·107*d*., against 0·42*d*. the cost for gas doing equal duties.

D. K. CLARK.

REPORT ON TESTS OF GAS COOKING-STOVES, 1882.

THIRTEEN gas cooking-stoves were tested for roasting joints from the sirloin, and for baking puff pastry, under the supervision of Mrs. Charles Clarke, Lady Superintendent of the National Training School for Cookery, South Kensington, who kindly volunteered to assist at the tests. The gas was supplied by the Gas-Light and Coke Company.

The gas cooking-stoves were of four types:—1st, having jets of luminous gas placed inside at the bottom;—2nd, luminous gas jets inside at the top, from which the heat was communicated by radiation and by reflection;—3rd, either luminous or atmospheric jets outside the oven;—4th, atmospheric jets inside at the bottom.

The annexed Table contains the results of tests of thirteen gas cooking-stoves in the order in which they were tested.

No. 1. CHARLES WILSON (type 4). A row of atmospheric jets at each side. It boils by means of atmospheric jets at the top. It is jacketed by an enclosed air-space 1 inch wide; the door is packed with slag-wool. (Plate 45.)

No. 2. J. C. STARK & Co. (type 3). Six Bray's jets in two rows, framed to swing outwards or under the oven as required. Atmospheric gas is used for boiling, &c. The stove is encased with slag-wool 2 inches in thickness. (Plate 45.)

No. 3. BROWNE & Co. (Beverley & Wilde) (type 4). Three rows of atmospheric jets inside, at the sides, and the back, with atmospheric jets at the top for boiling, &c. Lined with 1-inch tiles, and enclosed with a 2-inch layer of slag-wool.

No. 4. WADDELL & MAIN (type 1) ('Universal Domestic'). Four rows of jets, one at each side, and front and back. Lined with fire-tile. (Plate 46.)

No. 5. G. J. COX (type 4). 'Regenerator' Gas Stove. One side of the oven is coated with slag-wool; the other side is formed with an air-space in which the air for supplying the burners is previously heated. Three rows of atmospheric jets are placed at the sides and back, inside. Luminous jets at the top for boiling, &c. Cased in slag-wool 2 inches in thickness. (Plate 47.)

No. 6. B. GILES (type 3). Four luminous Bray's burners at one side only, next a narrow boiler which forms one side of the stove, and has a capacity of five gallons. The burners can be swung outside when required. The other side and the back are cased by an enclosed air-space.

No. 7. BILLING & Co. (type 2). A reflector stove, having luminous jets at the top, for which a row of holes is made in a pipe, half of which can be lit at a time. Atmospheric gas is used for boiling, &c. No extra casing.

No. 8. W. SUGG & Co. (type 4). Two rows of atmospheric jets at the bottom, one on each side. The joint was roasted on a spit in a copper cylinder placed in the oven, in which the spit was turned by means of clockwork. Atmospheric gas was used for boiling, &c.

No. 9. H. & C. DAVIS & Co. (type 4). Two rows of atmospheric jets, one at each side. Atmospheric gas is used for boiling, &c. Encased with slag-wool 1½ inches in thickness. (Plate 46.)

No. 10. J. DEAN & SON (type 3). Two atmospheric burners, one to the right at the bottom, and one to the left at the top; so that the temperatures at the top and the bottom can be regulated independently. The flame of the lower burner circulates through a flue covering the bottom of the oven, the left-hand side, and part of the back.

TABLE XXII.—RESULTS OF TESTS

No. of test	Date of test	Name of exhibitor	Type of stove	Dimensions of Roaster: Height	Depth	Width	Heating up the Stove: Time heating up	Temperature	Joint (Sirloin): Time roasting	Weight of joint on	Weight after roasting: Joint off	Dripping	Total	Loss of weight	
No.	1882			in.	in.	in.	min.	deg. F.	h. m.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	per cent.
1	Feb. 9	Charles Wilson	4	27½	15	15	12	250°	2 0	12 14	9 8	1 3	10 11	2 3	17
2	„	J. C. Stark & Co.	3	21	19	30	50	250	2 43	12 3	9 10	1 6	11 0	1 3	12½
3	„	Browne & Co.	4	24	14	13	15	250	2 33	12 8	10 14	1 4	12 2	6	4¾
4	„	Waddell & Main	1	22	14	13½	19	250	2 44	12 12	9 0	2 0	11 0	1 12	14
5	„	G. J. Cox	4	24	16½	16	25	250	3 0	12 1	9 11	1 1	10 12	1 5	12½
6	„ 10	B. Giles & Co.	1	12	15	16	25	250	3 0	12 11	10 13	15	11 12	15	12
7	„	Billing & Co.	2	12½ Pastry oven 9¾	18 15½	12¼ 11¼	5	250	2 43	12 2	9 8	2 4	11 12	6	5
8	„	W. Sugg & Co.	4	Copper cylinder			10	250	2 40	12 8	7 12	1 14	9 10	2 14	23
9	„	H. & C. Davis & Co.	4	26	17	15½	17	250	2 37	12 12	9 6	1 7	10 13	1 15	15¾
10	„	J. Dean & Son	3	8	14	12	19	250	2 45	10 12	8 7	1 6	9 13	15	14
11	„	S. Leoni & Co.	4	26	18	17	22	260	2 25	11 13	7 5	2 1	6 6	2 7	21
12	„ 14	W. Sugg & Co.	1	Copper cylinder			—	250	2 0	12 5	9 5	1 6	10 11	1 10	13¼
13	„	J. Wright & Co.	4	28	14	14	12	250	2 3	12 8	8 5	2 0	10 5	2 3	17½

The flame of the upper burner circulates between the top of the oven and the hot plate, from end to end, to and fro. The gas and air for combustion are mixed in a chamber covering the upper part of the back of the oven. The burners are 12 inches long, 6 inches deep, and 1½ inch wide, on the principle of the Davy lamp reversed, so that there is no lighting back. They give a sheet of flame 11½ inches by ¾ inch wide, and from 4 inches to 6 inches high. (Plate 47.)

No. 11. S. LEONI & Co. (type 4). Three rows of atmospheric jets at the sides and back. It is encased with slag-wool ¾ inch in thickness. (Plate 48.)

No. 12. W. SUGG & Co. (type 1). In this test, the copper cylinder alone (See No. 8), was employed for the test, not being placed in the oven. Two rows of luminous jets were burned inside the cylinder, one at each side. The joint was turned on a spit by clockwork.

No. 13. J. WRIGHT & Co. (type 4). Two rows of burners, one at each side. Encased with slag-wool 1½ inch thick. (Plate 47.)

An interesting series of tests were made, on the suggestion of Mrs. Clarke, with a view to ascertain the difference of condition of the joint, if any, relative to the mode of generating and applying the heat of the gas stoves.

For this purpose four typical stoves were selected, namely, No. 2 (Stark & Co.), No. 4 (Waddell & Main), No. 7 (Billing & Co.), and No. 11 (S. Leoni & Co.). The four quarters of one sheep were distributed to them, and were roasted at the same time, on February 13, 1882. The joints were, when cooked, immediately locked up under the charge of Mrs. Clarke, and were kept for several days. On February 20, they were examined independently by Mrs. Clarke and by her chief assistant, who formed the same opinion of the respective states of the joints. The results were as follows:—

				Condition.
No. 14.	Type 3.	J. C. Stark & Co. (No. 2).	Leg	just going off
No. 15.	„ 2.	Billing & Co. (No. 7).	Shoulder	bad
No. 16.	„ 4.	S. Leoni & Co. (No. 11).	Shoulder	not so bad as the following joint
No. 17.	„ 1.	Waddell & Main (No. 4).	Leg	very bad.

OF GAS COOKING-STOVES, 1882.

No. of test	Interval between joint and pastry	Puff Pastry: Time in oven	Puff Pastry: Temperature On	Puff Pastry: Temperature Off	Total time	Gas Consumed: Heating up	Gas Consumed: Roasting	Gas Consumed: Interval	Gas Consumed: Pastry	Gas Consumed: Total for joint and pastry	Quality of the Work done: Joint	Quality of the Work done: Pastry	Raising 5 lb. of Water to the Boiling Point in 8-inch Copper Standard Pan: Initial temperature	Boiling point	Rise of temperature	Time required	Gas consumed
No.	min.	min.	deg. F.	deg. F.	h. m.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub ft.			deg. F.	deg. F.	deg. F.	min.	cub. ft.
1	1	12	340°	380°	2 25	3·76	37·66	0·31	3·77	45·5	Fairly done	Moderate	46°	212°	166°	14	4·50
2	—	42	300	350	3 40	16·55		31·45		48·0	Very well done	Good	48	212	164	30	4·00
3	—	25	300	350	3 7	2·64		30·36		33·0	Well done	Fair	48	212	164	27	9·00
4	—	18	300	300	3 3	4·55		39·25		44·8	Well done	Fair	46	212	166	27	3·20
5	—	20	280	290	3 35	2·95		22·45		25·4	Underdone	Fair	48	212	164	27	3·80
6	1	27	310	390	3 53	8·40	61·0	0·34	9·26	79·0	Well done	Fair	48	212	164	28	4·00
7	—	28	310	400	2 48	1·20		38·80		40·0	Well done	Fair	48	212	164	21	7·00
8	—	13	320	390	2 50	6·24		97·76		104·0	Well done	Fair	46	212	166	27	10·00
9	1	17	340	400	3 12	3·01	27·80	0·18	3·01	34·0	Very well done	Very well done	46	212	166	16	4·00
10	6	27	320	400	3 37	5·08	44·10	1·60	7·22	58·0	Well done	Fair	48	212	164	29	8·00
11	3	10	340	360	3 0	7·09	46·72	0·97	3·22	58·0	Well done	Fair	46	212	166	17	4·00
12	—	10	300	350	2 10	—	—	—	—	53·0	Very well done	Fair	—	—	—	—	—
13	—	10	320	400	2 25	2·90	29·69	—	2·41	35·0	Well done	Fair	52	212	160	20	6·00

Three large gas cooking-ovens were tested for temperature simply, as it was thought they could not be properly tested by the cooking of one joint only, as follows:—

No. 18. Oven, by H. & C. DAVIS & Co., was constructed of sheet iron and was heated by three lines of atmospheric gas inside, at the sides and the back, at the bottom.

No. 19. Oven, by J. SLATER & Co., was heated in the same manner as No. 18. Air for ventilation enters at the top, passes down within the hollow walls and doors, enters at the bottom, passes upwards in mixture with the burned gases, and escapes at the upper part. (Plate 49.)

No. 20. Oven, by MART & BRADLEY, was heated by three rows of luminous jets fixed to the door at the inside near the bottom.

For heating the ovens, the gas was turned on at full power in each instance, and was regulated from time to time to maintain the temperature at 300° F. for one hour. The damper was closed during each trial.

TABLE XXIII.—RESULTS OF TESTS OF LARGE GAS COOKING-OVENS, 1882.

No. of test	Date	Name of exhibitor	Dimensions of oven: Height	Width	Depth	Heating up the oven: Time to heat up	Temperature	Coal-gas consumed: Heating up to 300 deg. F.	Maintaining temperature at 300 deg. F. for one hour	Total consumed
			ft. in.	ft. in.	ft. in.	minutes	deg. F.	cub. ft.	cub. ft.	cub. ft.
18	Feb. 20	H. & C. Davis & Co .	5 3	3 2	2 6	19	300°	—	—	77·5
19	”	J. Slater & Co . .	4 10½	3 7½	2 5½	15	300	27	36	63·0
20	”	Mart & Bradley . .	3 0	3 0	1 6	45	300	—	—	40·0

D. K. CLARK.

V. REPORT ON TESTS OF DOWSON'S GAS PRODUCER, FOR PRODUCING CHEAP GAS, AND OF THE APPLICATIONS OF THE CHEAP GAS.

It is known that highly-heating non-luminous gases can be produced by decomposing steam in the presence of incandescent carbon; and Dr. Siemens was the first to demonstrate, on a working scale, for regenerative furnaces, the economical advantages of cheap gaseous fuel. In Mr. Kidd's apparatus, patented in 1875, the chief novelty consisted of a coil of pipe within the generator, in which water was converted into steam, which was passed through the fire and was then decomposed. The calorific value of the gas produced in this manner was only one-fifth of that of London gas. Mr. J. Emerson Dowson, like Dr. Siemens and Mr. Kidd, passes a mixture of steam and air through a fire; and in addition he employs special means of generating and superheating the steam, in a simple and uniform manner. The steam-producer and superheater consists of a long coil of tube of such a form that nearly all of it is exposed to the action of gas flame. Water is forced, under a pressure of from 20 lbs. to 25 lbs. per square inch, into the coil, in which it is converted into superheated steam. The gas required for heating the coil is drawn from the gas-holder. The retort or generator is of iron, lined with ganister. The fuel rests on a grate, above an inclosed chamber into which a jet of superheated steam is directed through a small opening, carrying with it, by induction, a current of air into the furnace, for combustion. The gas produced contains, by volume, approximately, 20 per cent. of hydrogen, 30 per cent. of carbonic oxide, 3 per cent. of carbonic acid, and 47 per cent. of nitrogen.

The Dowson Gas-Generator or Producer, A size (Plate 65), exhibited by the Dowson Economic Gas Company, was tested for the manufacture of cheap gas, at the Manchester Smoke Abatement Exhibition, May 2, 1882. The anthracite, from Trimsaran, was supplied to the furnace, at the rate of 6 lbs. at a time, until 69½ lbs. in all was charged. The trial lasted 3 hours 5 minutes, and at the end of the trial 18½ lbs. of coal were withdrawn from the furnace, showing a net consumption of 51 lbs. of coal. The fire was got into working order in 30 minutes after lighting, when 30 lbs. of coal had been charged. Deducting the 18½ lbs. of coal withdrawn at the end of the trial, the balance (30 – 18½ =) 11½ lbs. was the quantity actually consumed in getting up the fire. The remainder of the total coal consumed, (51 – 11½ =) 39½ lbs., was consumed, in actually generating gas, in 2 hours 33 minutes: being at the rate of 15½ lbs. per hour.

The quantity of water consumed during the period of test, 3·05 hours, was 2·375 gallons, or 23·75 lbs., being at the rate of 7·80 lbs. per hour, and 0·466 lb. per pound of coal consumed.

The gas was generated at the rate of 1177·5 cubic feet, delivered net, per hour, being exclusive of the gas consumed in generating steam. This portion of gas is estimated at the rate of 100 cubic feet per hour, and makes a gross total of 1,277½ cubic feet of gas generated per hour. As the coal was consumed in generating gas at the rate of 15½ lbs. per hour, the following are the quantities of coal per 1,000 cubic feet:

$$15{\cdot}5 \times \frac{1{,}000}{1{,}277\frac{1}{2}} = 12{\cdot}13 \text{ lbs. per 1,000 cubic feet of gas, gross.}$$

$$15{\cdot}5 \times \frac{1{,}000}{1{,}177\frac{1}{2}} = 13{\cdot}17 \text{ lbs. per 1,000 cubic feet of gas, net.}$$

The cost of production of cheap gas may be taken, for A generator, as follows:—

	s.	d.
Anthracite to make gas, at the rate of 1,000 cubic feet per hour, 12·13 lb. × 9 working hours per day = 109 lbs. or, say, 1 cwt. at 16*s.* per ton	0	9½
Wages	1	0
Maintenance, 5 per cent. on 125*l.* per working day	0	5
Interest on capital, 5 per cent.	0	5
Total	2	7½

Gas produced in one day of 9 hours	9,000 cubic feet
Less gas used in the apparatus, say	1,000 „
Net gas, for 2*s.* 7½*d.*	8,000 „

Net cost, say, 4*d.* per 1,000 cubic feet.

The Dowson Cheap Gas was tested for the production of motive power, and for heating and other purposes, as follows:—

I. Working an Otto Gas Engine of 3½ Horse-Power at the Smoke Abatement Exhibition, South Kensington.

The system of construction of the Otto gas engine is described in the report of the test of the engine with coal gas. It suffices to say now that the engine is single-acting, and makes an explosion of gas every alternate outward stroke. The cylinder of the 3½ horse-power engine is $6\frac{1}{16}$ inches in diameter, with a stroke of 12 inches.

The engine made 156 revolutions per minute during the test. The fly-wheel was 60½ inches in diameter, and it sustained a net load of 43 lbs. on a belt passed round the circumference, proving that 3·26 horse-power was exerted at the brake.

Several indicator diagrams were, at the same time, taken from the cylinder; from which it was calculated that an effective mean pressure of 53·13 lbs. per square inch was exerted on the piston, for each explosion; making 4·41 indicator horse-power.

The horse-power at the brake was 74 per cent. of the indicator horse-power. The consumption of cheap gas was at the following rates:—

110·34 cubic feet per indicator horse-power.
149·30 „ brake „

The anthracite was consumed at the following rates:—

$$13{\cdot}17 \text{ lbs.} \times \frac{110{\cdot}34}{1{,}000} = 1{\cdot}45 \text{ lbs. per indicator horse-power.}$$

$$13{\cdot}17 \text{ lbs.} \times \frac{149{\cdot}30}{1{,}000} = 1{\cdot}07 \text{ lbs. per brake horse-power.}$$

The cost for cheap gas for motive power in the test, calculated at the rate of 4*d.* per 1,000 cubic feet, was ·44*d.* per indicator horse-power per hour, against 0·95*d.* for coal gas as deduced from the test of the Otto Gas Engine exhibited by Crossley Brothers, worked by coal-gas.

II. Heating of the Larger Division of the Gas Cooking or Roasting-Oven of J. Slater & Co.

J. Slater & Co.'s Roasting-Oven has already been noticed in the Report on Tests of Gas Cooking-Stoves (page 111). The objects of the test were: to determine the quantity of gas and the time necessary to raise the temperature of the oven to 300°; and the quantity required to maintain this temperature for one hour. The results for coal gas are given for comparison:—

	Coal gas	Cheap gas
Initial temperature of the air	58° F.	57° F.
Gas consumed in heating up to 300° F.	27 cub. ft.	90 cub. ft.
Time occupied	15 min.	15 min.
Gas consumed in maintaining the temperature 300° F. for one hour	36 cub. ft.	220 cub. ft.
Total gas consumed in 1¼ hour	63 cub. ft.	310 cub. ft.
Pressure of gas	1·2 inches	1·5 inches
Cost of gas for one hour, at the rate of 3*s.* per 1,000 cubic feet for coal gas, and 4*d.* for cheap gas	1·3*d.*	0·88*d.*

III. In a Gas Singeing Machine.

Blanche's Gas Singeing Machine, for cotton, woollen, and silk goods, was exhibited by Joseph Robinson & Co., Salford, at the Manchester Smoke Abatement Exhibition. It was frequently in operation, supplied with Dowson's Cheap Gas, manufactured in the building. It is exhibited also at the Industrial Exhibition, Bradford. The principal novelty of Blanche's machine consists in the use of long slit-burners, with large mixing chambers, into which gas and compressed air are introduced. The proportions of these are regulated by means of cocks, so that the heating power of the flames can be adapted to the various kinds of material to be singed. The speed of transit of the web can also be regulated: varying from 50 to 70 yards per minute. It was not practicable to singe a piece of cloth long enough for making a trustworthy trial, as only a few hours could be spared for the purpose.

Data, nevertheless, exist, embracing the results of trials with coal gas; and it was thought that by proving the relative heating-power of coal gas and Dowson gas in raising the temperature of water in a trough placed over the slit-burner, a comparative test could be made of the proportional quantities of the two gases that would be consumed on the same kind of work. The experimental trough was made of tin, six inches high, six inches wide, and four feet long, open at the top, and having the bottom slightly concave towards the flame. The crown of the concave bottom was ¾ inch clear of the burner; the length of the flame under the trough was 3 feet 11 inches. The air-blast had a pressure of ten inches of water. The inner blue flame, caused by the air-blast, was about half an inch high.

Two gallons of cold water at 57° F. were heated in the trough up to 212° F., the boiling point, in 13½ minutes, with a consumption of 12½ cubic feet of Corporation coal gas, of 0·7 inch pressure.

Three like tests were made with Dowson gas:—

Test	Initial temperature	Time to raise the temperature to 212° F.	Dowson-gas consumed. Pressure 1¼ inches
	deg. F.		
1	68	7 min. 0 sec.	49 cubic feet
2	68	8 „ 10 „	49 „
3	58	8 „ 30 „	50 „

It appears that exactly four times as much of the Dowson Cheap Gas was consumed as there was of coal gas in doing equal heating duty; and, taking the respective prices of the gases at 3*s.*, and at 4*d.* per 1,000 cubic feet—in the ratio of 9 to 1—it would follow that, as only four times as much Dowson gas was consumed as of coal gas, the cost for Dowson gas would be less than half the cost for coal gas. This deduction is confirmed by the experience of the exhibitors of the singeing machine, who find that the work is done with the Dowson gas at half the cost for coal gas.

D. K. CLARK.

VI. REPORT ON TESTS OF APPARATUS FOR HEATING ROOMS AND BUILDINGS BY HOT-AIR, HOT-WATER, AND STEAM CIRCULATION, 1881-82.

THE testing of Kohlhofer's Hot-Air Stove has already been noticed in the Report for Open Grates and Stoves (p. 49), and in Table III.

WILLIAM WHITE, F.S.A.—The 'Shrewsbury' Warming Apparatus, exhibited by Mr. White, consists of a brick structure enclosing a furnace and air-heating chamber, to supply heated air for warming churches, schools, and other large buildings. The furnace is constructed of fireclay slabs 2 inches thick at the sides, and 3 inches at the bottom, and consists of a shallow oblong fire-place, surmounted by a rectangular hopper at the further end, into which the fuel is charged at the top, from the front. The fire-grate is 17 inches by 21 inches. The hopper is placed in a cubical iron box, formed with gills to absorb and distribute the heat to the air surrounding it and enclosed by the outer structure of brick. The draught, after having ascended through the fuel in the hopper, turns over each side at the back, and descends to the lower part, whence it re-ascends by a central flue into a 6-inch iron flue-pipe placed inside the chimney. Fresh air from the outside is introduced at the lower part, and surrounds the iron casing of the furnace; thence it passes into a chamber above the furnace, and into the chimney, surrounding the flue-pipe. The lower portion of the chimney is blocked off by a partition plate, through which the flue-pipe passes and conducts the products of combustion; and the warmed air escapes through an opening in a side of the chimney measuring 14½ inches by 19½ inches, equal to 1·94 square feet in area.

In this apparatus, the fire does not touch the iron heating-plates; the whole of the combustible gases pass through the incandescent fuel in the retort.

This air-warmer was tested, January 3, 1882, burning coke as fuel. During a trial lasting twenty-three hours, 144 lbs. of coke was consumed, being at the rate of 6¼ lbs. per hour. The fresh air entered at a temperature of 47° F., and issued at temperatures of from 56° at the commencement to 195°, averaging 141½° during the first six hours; and at a velocity of from 75 feet per minute to 320 feet per minute, averaging 244 feet per minute, during the same time. At the end of the period of trial, the temperature of the issuing current was 85°, and the velocity was 210 feet per minute. The mean of these observations, ($141\frac{1}{2} + 85 = 226\frac{1}{2} \div 2 =$) 113° F., and ($244 + 210 = 454 \div 2 =$) 227 feet per minute, are approximately the average temperature and velocity for the whole time; equivalent to ($1 \cdot 94$ square feet $\times 227 =$) 440 cubic feet per minute, or 26,400 cubic feet per hour, at 113° F.

Tested with anthracite, January 11, 1882, for a period of 22¼ hours, the furnace consumed 126 lbs., being at the rate of 5·66 lbs. per hour. Fresh air at 50° was heated to an average of 197° for the first five hours; at the end of the trial the air issued at 140°, making an approximate mean temperature of 169°. The average velocity was 291 feet per minute for the first six hours, and 220 feet per minute at the end of the trial, making a mean velocity of 256 feet per minute, equivalent to ($256 \times 1 \cdot 94 =$) 49,664 cubic feet per hour at 169°.

FRANKLIN, HOCKING & Co.—The hot-water apparatus for warming greenhouses, halls, &c. (Plate 64), was tested in room No. 5, December 10–12, 1881. It consisted of a small

stove, connected with two circuit-lines of cast-iron pipes, through which the heated water circulated, leaving the stove at the upper part and returning to it at the lower part, after having twice made the circuit of the room. The boiler is vertical, of the form of a truncated cone, made with a shell and a fire-box, inclosing a 1½-inch water-space for the circulation of water. It is 18¾ inches in diameter at the bottom, and 13 inches at the top. The grate is circular, 14 inches in diameter. The boiler stands on an ashbox. It is fed from a hopper, consisting of a cylinder 15 inches in diameter and 24 inches deep, placed on the top of the boiler, delivering into an 8-inch tube, depending into the boiler for two-thirds of the depth, and surrounded by a water jacket. The upper cylinder is only employed for long periods of heating. The burnt gases escape direct from the upper part by a flue to the chimney. The circulating pipes are 3 inches in diameter inside, and have a total length of 160½ feet, presenting on the outside 136½ square feet of area for warming by conduction and radiation. The coils are 5½ inches apart between their centre-lines, and the centre of the lower coil is 11 inches above the floor. (Plate 64.)

For the test, 2 lbs. of wood and 114 lbs. of gas-coke were consumed in 45½ hours, from December 10 to 12, the consumption of coke being at the rate of 2½ lbs. per hour. The external temperature was 36° F.; the initial temperature of the room was 42°; the maximum temperature attained in the room, at a height of 6 feet from the floor, was 50°, and the average temperature for the whole period was 49°·23. The average rise of temperature was (49°–42°=) 7°·23, being at the rate of 2°·90 per pound of fuel.

The same system of warming-pipes was heated by gas, which was burned in a cylindrical vertical boiler, in which the burnt gases rise through a central cylinder, water-jacketed, and through annular spaces surrounding it, into the upper part, whence they escape into the flue. The test, which was made December 14, 1881, lasted 6 hours 40 minutes, with a consumption of 330 cubic feet of gas, being at the rate of about 50 cubic feet per hour. The initial temperature of the room was 39° F.; the maximum temperature averaged 57°, and the average temperature during the test was 49°, making an average rise of 10°. To compare these results with those deduced for gas-heating stoves (Table XXI. p. 104), add, according to the rule already practised, one half to the observed rise, making 15°, to give the equivalent rise as for one of the smaller testing rooms:—

	Hocking	Gas-stoves
Rise of temperature per cubic foot of gas per hour . . .	0°·30	0°·20
Do. per 10 cubic feet do. . . .	3°·00	2°·00

W. & S. Deards.—The Portable Coil Stove was tested January 2, 1882, in room No. 2, burning anthracite. It consists of a cylinder of cast-iron, having a coil of pipe inside, through which water circulates and from which heat is distributed. The fuel is burned within the coil, on a cast-iron grid. The furnace is surmounted by a hopper, which is filled with a supply of coal sufficient to last 26 hours. The draught ascends from the bottom, and passes out at the upper part at the back. The test trial lasted 24 hours, during which 34·4 lbs. of anthracite were consumed, being at the rate of 1·43 lb. per hour. The external temperature was 50° F., the initial temperature in the room was 48°, the average temperature for the whole period was 64°·25, showing a rise of temperature averaging 16°·25, being at the rate of 11°·4 per pound of coal consumed per hour. The measure of radiation was 5° at a height of 5 feet, at a distance of 6 feet from the fire. (Plate 65.)

W. & S. Deards.—The Open Coil Grate is made up of a coil of water-piping—sides, back, and front—with a cast-iron grid. The two ends of the coil are supposed to be connected to pipes leading to other rooms, the water being heated and circulating through the piping. This grate was tested in room No. 2, January 4, 1882, for 24 hours. Of anthracite, 57·2 lbs. were consumed—at the rate of 2·40 lbs. per hour. The external temperature was 38° F.; the initial temperature in the room was 55°; and

the average temperature at the walls was 72°, showing an average rise of 17°, being at the rate of 7°·10 per lb. of coal consumed per hour. (Plate 65.)

A large boiler on the same principle, in brickwork, is shown in Plate 64.

W. Stainton exhibited his Frost-proof Hot-water Apparatus. The stove is cubical, of wrought iron, 18 inches square and 30 inches high. The fire-place consists of a coil of pipe ⅞-inch bore and 1⅜ inch in diameter outside, comprising five rings of pipe, with a cast-iron grid at the bottom. The stove is lined with firebrick below the coil and above the coil, and also on the roof. The draught proceeds between the upper coils at the front, and is split, passing round each side of the stove, outside the coil, to the back, whence it goes off by the flue. There is an automatic-supply cistern, and a feed-valve, and a safety-valve. A branch from the heating coil is led to the cistern; it is formed with a T end, of which the upright part is fitted with two valves, the lower of which is the vacuum-valve, and the upper is an expansion-valve, which opens when the water expands, and provides an overflow into the cistern, afterwards re-closing. The boiler is fitted with a pump for supplying it with water, and for extracting air and dirt. The heating coil of pipe, of the same size as the piping forming the fire-place, is disposed as a rectangular pile of piping about 5 feet long, 12 inches wide, and 2 feet high, making a length of 143 feet of pipe. It was placed in the middle of the floor of No. 5 testing room, and was connected with the stove, which was placed outside the wall of the room, so that a continuous circulation of water was maintained. The test lasted 5 hours, during which period 2 lbs. of firewood and 25¼ lbs. of coke were consumed, being at the rate of 5·05 lbs. of coal per hour. The external temperature was 42° F.; the initial temperature in the room was 45°; the maximum temperature was about 80°; and the average temperature for the whole period, at a height of 6 feet, was 63°: showing a rise of 18°, being at the rate of 3°·56 per pound of coke. The pressure maintained in the tubing averaged about 640 lbs. per square inch.

Comparison.

Summarising the results of the tests of hot-water apparatus, they are briefly as follows:—

Table XXIV.—RESULTS OF TESTS OF HOT-WATER HEATING-APPARATUS.

Test	Room	Apparatus	Fuel	Period of test	Rise of temperature per lb. of fuel
				hours	degrees F.
1	No. 5	Franklin, Hocking & Co., hot-water pipes	Anthracite	45¼	2·90 F. actual 4·35 F. equivalent
2	No. 2	Deards, portable coil-stove	Anthracite	24	11·4 F.
3	No. 2	Do. open coil-grate	Anthracite	24	7·1 F.
4	No. 5	Stainton, hot-water tubing	Coke	5	3·56 F. actual 5·34 F. equivalent

Here, the rise of temperature for No. 5 room has been augmented by one-half, as before explained, to bring it into comparison with the rise for No. 2 room. Evidently, Messrs. Deards' performance shows by much the greatest rise of temperature per pound of fuel, though the test lasted little more than half as long as Mr. Hocking's. Mr. Stainton's test lasted only one-fifth of the time of Messrs. Deards'; and, although his average rise of temperature was less than Messrs. Deards', yet, regarding the very short period of his test, it is reasonable to conclude that, had it been extended to 24 hours, he would have made as great a rise of temperature per pound of fuel as Messrs. Deards have done.

D. K. CLARK.

VII. REPORT ON TESTS OF

The exhibited steam-boiler appliances are directed for the most part specifically to the prevention or consumption of smoke from coal. There are a few which are directed to the better general treatment of fuel, not only for effecting complete com-

TABLE XXV.—RESULTS OF TESTS OF

I. *Fixed*

No. of test	Name of exhibitor	Date of trial	Time under trial	Coal Consumed			
				Description	Total	Per hour	Per square foot of grate per hour
1	2	3	4	5	6	7	8
			h. m.		lbs.	lbs.	lbs.
1	Chubb & Co.	Sept. 19, 1881	43	Slack	—	—	—
2	E. L. Gowthorpe	Nov. 9 "	1 31	Mixed	594	210	7·63
	Do. apparatus not at work	" 9 "	50				
3	G. Hunter & Co.	" 11 "	1 21	Slack	—	—	—
	Do. apparatus not at work	" 11 "	—	Do.	—	—	—
4	Ireland and Lownds	" 24 "	3 15	Mixed	431	133	21·3
	Do. apparatus not at work	" 24 "	2 40	Do.	580	217	34·8
5	W. Pickering	" 14 "	6 10	Slack	613	99	4·73
6	J. Cornforth	Feb. 11, 1882	5 0	Do.	672	134	6·4
7	Duncan Brothers (Welton), with grid	Jan. 20 "	5 15	Hard steam	784	149	25·1
	Do. without grid	" 23 "	5 15	Do.	930	177	30·0
	Do. with grid	" 26 "	5 15	Do.	678	129	21·72
	Do. without grid	" 28 "	5 15	Do.	840	160	27·0
	Do. without grid	Feb. 1 "	4 5	Do.	672	165	27·8
8	B. W. H. Schmidt	Nov. 15, 1881	4 0	Slack	640	160	7·62
9	L. Juillard	" 19 "	4 0	Do.	560	140	6·70
10	Elliott	Dec. 24 "	6 15	Do.	1,064	170	8·10
	Do. out of action	" 24 "	—	—	—	—	—
11	The Great Britain Smoke Consuming Company	" 28 "	6 2	Slack	1,260	210	10·0
	Do. out of action	" 29 "	6 15	Welsh coal	1,232	197	9·39
	Do. in action	" 30 "	5 55	Do.	896	151	7·20
	Do. in action	Mar. 8, 1882	5 0	Do.	704	141	6·71
	Do. out of action	" 9 "	5 0	Do.	672	168	8·00

STEAM BOILER APPLIANCES, 1881-1882.

bustion, but also for improving the evaporative efficiency of the fuel. Results of tests are given in the Table annexed. Exhibits Nos. 1 to 13 and No. 19 in the Table are specifically directed to the prevention of smoke. Exhibits Nos. 22 to 26 are mechanical stokers.

STEAM-BOILER APPLIANCES, 1881–82.

Appliances.

No. of test	Water Evaporated				Smoke, by Smoke-Scale					Pressure of steam, lbs. per square inch	Description of apparatus
	Temperature	Total	Per hour	Per lb. of coal	Maximum density	Average density	Average duration for one firing	Average length of time			
								Visible	No smoke		
	9	10	11	12	13	14	15	16	17	18	19
	deg. F.	cub. ft.	cub. ft.	lbs.	No.	No.	min.	per cent.	per cent.	lbs.	
1	—	—	—	—	6	3·6	0·70	1·6	98·4	60	Cast-iron air-bridge
2	54°	82	29·0	3·05	{6	2·5	1·00	2	98}	60	Cast-iron air-bridge
					{9	5·0	Continuous	100	0}		
3	—	—	—	—	6	3·0	3·00	20	80	38	{ Cast-iron bridge and fireclay arch perforated
	—	—	—	—	9	5·3	4·50	—	—	—	
4	43	42·6	13·1	6·15	4	2·0	4·25	43	57	45	Cast-iron air-pipes at bridge
	43	47·0	17·6	5·05	10	6·75	9·50	84	16	28	
5	—	90·5	14·7	9·20	9	4·33	7·50	27	73	23	Hollow fire-bars passing air to bridge
6	—	101·6	20·33	9·44	8	3·20	Continuous	—	100	45	Hollow fire-bars passing air to bridge.
7	—	60·22	11·47	4·78	1	0·33	—	—	—	20	} Asbestos grid in flue to intercept and burn smoke
	—	55·74	10·62	3·73	4	2·70	Continuous	100	0	20	
	—	52·65	10·3	4·84	1	0·40	—	—	—	20	
	—	56·8	10·8	4·23	2	1·00	Continuous	100	0	20	
	—	42·1	10·3	3·90	2	·60	—	—	—	20	
8	—	—	—	—	8	3·0	6·0	40	60	48	Jet of steam above the door
9	—	71·3	17·8	8·00	8	3·4	2·5	15	85	48	Steam and air above door
10	—	114·0	18·2	6·70	10	2·22	2·25	22	78	40	} Steam and air at sides of furnace
	—	—	—	—	10	3·50	16·0	—	100	—	
11	—	137·5	22·8	6·81	—	—	—	—	—	42	} Steam and air through tubes at front of furnace
	57	162·3	26·0	8·20	—	—	—	—	—	42	
	58	132·6	22·4	9·22	2	1·0	0·50	4	96	42	
	—	101·0	20·20	8·84	4	2·53	Continuous	100	0	40	
	48	72·23	18·06	6·70	5	2·1	6·00	40	60	41	

TABLE XXV.—RESULTS OF TESTS OF STEAM-BOILER

No. of test	Name of exhibitor	Date of trial	Time under trial	Coal Consumed			
				Description	Total	Per hour	Per square foot of grate
1	2	3	4	5	6	7	8
			h. m.		lbs.	lbs.	lbs.
12	W. A Martin & Co.	Jan. 18, 1882	6 0	Nixon	2,128	355	11·82
	Do.	„ 19 „	4 18	Northumbrlnd	2,016	502	16·73
	Do.	„ 20 „	5 5	Do. washed small	2,968	584	19·50
	Do.	„ 21 „	5 10	Do. rough small	2,576	495	16·50
	Do. (reduced grate)	Feb. 17 „	4 10	Northumbrlnd	1,792	430	20·87
13	A. C. Engert, horizontal boiler	Sept. 20, 1881	2 19	Hard steam and slack	342	147	8·42
	Do. do.	„ 28 „	2 50	Hard steam	429	152	8·66
	Do. do.	Nov. 1 „	2 53	Do.	504	174	10·00
14	A. C. Engert, vertical boiler	„ 17 „	4 49	Do.	104	21·6	7·34
	Do. do.	„ 21 „	2 0	Do.	101	50·6	17·21
15	J. Collinge (Blocksage)	Oct. 19 „	4 47	Slack	1,400	293	28·60
16	J. Farrar & Co.	Nov. 25 „	3 48	Do.	972	256	—
17	J. Wavish	Sept. 9 „	5 17	Hard steam	918	173	16·90
	Do.	Oct. 12 „	5 0	Wear fuel	917	183	17·90
18	Livet's Boiler and Furnace Company[1]	Sept. 22 „	6 13	Aberdare Rhondda	833	134	7·31
19	G. Haller and Co., in operation	Oct. 31 „	6 54	Welsh	1,960	284	10·84
	Do. common grate	„ 14 „	3 50	Do.	1,241	324	12·15
20	E. G. Wéry, in operation	Jan. 1882	5 50	Hard steam	303	52	10·40
	Do. not in operation	„ 6 „	6 0	Do.	391	65	13·00
	Do. in operation	„ 18 „	5 0 (evaporating 4·23)	Do.	282	56·4	11·30
	Do. not in operation	„ 17 „	5 0 (evaporating 4·12)	Do.	365	73	14·60
21	J. M. Stanley	April 3 „	3 21	Slack	276	82·4	27·46

II. *Mechanical*

23	The Patent Steam Boiler Company	Oct. 26, 1881	—	—	—	—	—
24	G. Sinclair	Dec. 15 „	7 3	Slack	1,650	232	19·4
25	Knowles and Halstead	Nov. 18 „	5 0	Do.	903	180·6	11·78
	Spreading fires.						
26	J. Proctor	„ 10 „	4 43	Slack	2,912	613	20·4
	Do. hand-firing	„ 10 „	—	Do.	—	—	—
27	J. Newton & Son	Oct. 20 „	2 50	Do.	1,400	494	16·8
	Do. hand-firing	„ 20 „	3 0	Do.	1,568	522	17·4

[1] See also results of tests of various Welsh coals and

APPLIANCES, 1881–82—(*continued*). I. *Fixed Appliances*—(*continued*).

No. of test	Water Evaporated: Temperature	Water Evaporated: Total	Water Evaporated: Per hour	Water Evaporated: Per lb. of coal	Smoke, by Smoke-Scale: Maximum density	Smoke, by Smoke-Scale: Average density	Smoke, by Smoke-Scale: Average duration for one firing	Smoke, by Smoke-Scale: Average length of time: Visible	Smoke, by Smoke-Scale: Average length of time: No smoke	Pressure of steam lbs. per square inch	Description of apparatus
	9	10	11	12	13	14	15	16	17	18	19
	deg. F.	cub. ft.	cub. ft.	lbs.	No.	No.	minutes	per cent.	per cent.	lbs. steam	
12	83	400	66·7	11·69	3	1·2	1·00	6	94	Atmo-spheric	Balanced fire-door
	92	353	82·1	10·87	4	2·2	2·20	13	87		
	89	409	80·5	8·56	2	0·75	1·00	3	97		
	93	369	71·0	8·90	2	0·90	1·01	9	91		
	84	321	77·0	11·14	4	1·80	6·50	43	57		
13	100	48·3	20·82	8·76	4	1·50	5·0	45	55	30	Swivel-shutter, internal
	100	61	21·54	8·81	2	—	1·10	12	88	30	
	80	62	21·40	7·62	4	1·2	1·60	12	88	30	
14	59	6·26	1·30	3·75	2	1·00	Nearly continuous	0	100	30	Side firing
	59	7·06	3·53	4·34	—	2·10	Do.	0	100	30	
15	—	147	30·72	6·55	0	0	0	0	100	Atmosph.	Inclined brick furnace
16	63	105	27·7	6·76	0	0	0	0	100	33	Stage-furnace of brick
17	130	120·2	22·7	8·06	0	0	0	0	100	20	Vertical grates within furnace
	122	118·8	23·4	7·87	4	1·8	2·25	18	82	35	
18	60	163·7	26·3	12·25	0	0	0	0	100	61	Deep fire-bars, and enlarging flues
19	47	287·3	41·6	9·15	2	1·0	2·50	12	88	40	Short fire-bars 9 inches long
	—	158·5	41·4	7·98	0	0	0	0	100	40	Common grate
20	51	36·9	6·33	7·41	5	3·0	Continuous	100	0	20	Atmospheric chimney
	—	27·8	4·63	4·43	9	6·5	Do.	100	0	20	
	48	27·7	6·30	6·13	10	8·0	Do.	100	0	20	
	—	22·6	5·58	3·87	10	8·0	Do.	100	0	20	
21	52	19·8	5·91	4·48	10	3·22	1·67	7½	92½	27	Vertical retort-furnace

Stokers.

23	—	—	—	—	4	2·0	Continuous	100	0	35	Knap's mechanical stoker; coking fire
24	419	140·4	20·0	5·36	0	0	0	0	100	50	Coking fire; flash flue
25	60	133·5	26·7	9·22	10	4·4	2·6	16	84	70	Holroyd-Smith's under-feed
26	310	424	89·25	8·99	5	2·6	Continuous	100	0	95	Shovel-spreading stoker
	—	—	—	—	10	5·7	,,	100	0	95	Hand-firing
27	140	192·6	68·00	8·44	—	—	—	—	—	Atmosph.	Spreading fire with hot-air blast
	137	196·3	65·45	7·67	—	—	—	—	—	,,	Ordinary spreading fire

anthracites in this boiler, in the Report on Results of Tests of Fuels.

FIXED APPLIANCES.

No. 1, Chubb & Co., consists of a hollow cast-iron bridge, applied at the back of the furnaces of internally-fired boilers, semi-circular in outline, and leaving a semi-annular flue-way between the bridge and the upper part of the boiler. The bridge is faced with a thick fire-tile next the fire, and it is formed with three transverse slits about an inch wide, through which streams of heated air are delivered successively into the currents of gases from the furnace as they pass over the bridge. Intermixture is thus effected, and the combustion of unconsumed gases is promoted. A separate current of air is admitted into the front part of the bridge, and is delivered obliquely downwards, through apertures, above the fire. Air is admitted from the ash-pit into the bridge, and the supplies are regulated by means of two valves. This apparatus was tested while at work at the East London Waterworks, Old Ford; at the Candle Works of Messrs. Field, Lambeth; and at Mr. McMurray's Royal Paper Mills, Wandsworth. In each case the system was effective to a material degree in preventing smoke. The results of observations on the smoke at the last-named place are recorded in the Table, showing that smoke was visible for a very limited proportional period—namely, 1·60 per cent. of the whole time. But the rate of combustion in the boilers at that establishment was moderate, and the consequent quantity of smoke to be prevented was also moderate. (Plate 50.)

No. 2, E. L. Gowthorpe, 'West's Smoke Consumer,' comprises a hollow cast-iron bridge, in the backward face of which a wide horizontal slot is formed close to the upper part, through which a stream of air, admitted from the ash-pit, is delivered horizontally, falling in with, and gradually commingling with and consuming, the combustible gases passed over the bridge. An additional supply of air is delivered from a long slot in a tube carried across the flue, a little behind the bridge, to which the air is led through a pipe from the front of the boiler. This system, as employed at and tested at the works of Messrs. Sylvester & Co., Nottingham, was remarkably effective in preventing smoke, smoke being apparent for only 2 per cent. of the time, and there not being any smoke for 98 per cent. of the whole time. The boiler was 6½ feet in diameter and 20 feet long, having two flue-tubes 2½ feet in diameter. For comparison, the same furnace was tested in ordinary condition, when the apparatus was put out of work. The results, given in the Table, show that smoke averaging No. 5 on the scale lasted all the time. But the evaporative efficiency, taken together, with and without the apparatus, was low,—only 3·05 lbs. of water evaporated per lb. of mixed coal, large and small. (Plate 50.)

No. 3. G. Hunter & Co.—This apparatus consists of a hollow cast-iron bridge, having a slot across the top of it for the emission of warmed air upwards to meet the gases from the fire; and, in addition, a hollow brick arch turned in the flue a short distance beyond the bridge, from which streams of warmed air were discharged into the flue above the combustible gases proceeding from the bridge. The combustible current was thus encountered by air from above as well as air from below. The preventive action in this system, in operation at the works of Messrs. Hebbert & Co., Leeds, was very considerable, in comparison with the work of the same furnace when the apparatus was put out of operation, as is indicated in the second line of No. 3 in the Table. The boiler was 7 feet in diameter, having a 3-feet fire-tube.

No. 4. Ireland & Lownds.—This apparatus consists of a number of cast-iron pipes of Γ-form, one limb of each of which is laid upon the bridge, the other limbs hanging down in front of the bridge. The pipes are closely laid so as to form a bridge of cast-iron. Air from the ash-pit is admitted into the tubes at the lower end, and, being heated in its progress, is discharged through finely divided grids at the upper part at

the further end, where it meets the combustible gases from the furnace. This apparatus was applied to the boiler at the works of Messrs. Clowes & Stafford, Leek. The boiler is 5 feet in diameter and 16 feet long, having a flue 2 feet 4 inches in diameter. The apparatus was very efficient in consuming smoke, although it appears in the Table that smoke was visible during 43 per cent. of the time. But, looking to the deneseness and persistence of the smoke when the apparatus was blocked up, as shown in the second line of No. 4, it is obvious that the system did great execution in improving the combustion of an obstinately smoky fuel, and in augmenting its evaporative efficiency (column 12) from 5·05 lbs. of water per lb. of slack, without the apparatus, to 6·15 lbs. with it. This contrast should be taken with the qualification that the rate of combustion (column 7) was forced up to a much greater degree without the apparatus than with it, helping partly to account for the inferiority of evaporative efficiency. But it appears that steam of only 28 lbs. per square inch was maintained without the apparatus, against 45 lbs. with it. (Plate 51.)

No. 5. W. PICKERING.—This apparatus consists of hollow fire-bars, through which air is admitted at the front of the furnace, from beneath the dead-plate, and from which, being turned upwards at the end, the heated air is discharged close to the bridge into the current of combustible gases from the furnace, in order to consume them. Additional supplies of air are admitted between the fire-bars, at the bridge, mingling with the heated air from the bars, in the rising portion of the bars. Another bridge or wall is constructed in the flue, at a short distance behind the ordinary bridge, through which a circular opening is made, for the concentration of the gases after they have passed over the first bridge: so promoting combustion, at the same time that the current is deflected downwards, and prevented from striking the boiler. This apparatus was tested at one of the boilers, under-fired, at the Royal Albert Hall; but the supplementary bridge was not constructed.

No. 6. J. CORNFORTH.—This apparatus, resembling Pickering's, consists of hollow fire-bars discharging the heated air which passes through them into a hollow bridge made with cast-iron gills, to form conduits for the delivery of the air upwards over the bridge. This system was tested on one of the boilers, under-fired, at the Royal Albert Hall.

No. 7. DUNCAN BROTHERS.—Welton's apparatus consists of an iron grid laid diagonally within the internal flue of a Lancashire or a Cornish boiler, beyond the ordinary bridge, the lower end inclining towards the bridge. This grid is covered with small lumps of asbestos, the function of which, being heated to redness, is to intercept and intermingle the smoke and air passing from the furnace, and effect their combustion by imparting heat to the mixture. This apparatus was tested on a Cornish boiler, erected in the Exhibition, without external flues, and without covering: the gaseous products proceeding from the internal flue direct to the chimney. The boiler was 4 feet in diameter and 14½ feet long, having a 2½-feet fire-tube. The evaporative efficiency (column 12) was materially augmented by the employment of this asbestos grid. But, further experience of the apparatus, in boilers properly set and under ordinary conditions, is needed to afford data for a final judgment on it. The proportion of visible smoke also was diminished by its use. (Plate 52.)

No. 8. B. W. H. SCHMIDT.—In this apparatus steam is led by a pipe from the boiler into a small chamber placed inside the furnace, just above the doorway, from which the steam is discharged in streams over the fire, in the direction of the bridge. The fire-door is at the same time kept open two or three inches, so that air entering there is drawn in and dispersed by the streams of steam amongst the gases in the furnace. This apparatus was tested on one of the boilers at the Royal Albert Hall.

No. 9. L. JUILLARD.—Jets of steam are discharged from a hollow globe through

perforations from above the doorway. Over the fire, air is also permitted to flow with the steam into the furnace. This apparatus was tested on one of the boilers at the Royal Albert Hall.

No. 10. J. Elliott.—In this apparatus, air is introduced from the ash-pit, through passages constructed in the sides, into horizontal tubes placed just above the level of the fire, and directed obliquely towards the bridge. A jet of steam is delivered through each tube, and draws or induces the air with it, so as to be mixed with the combustible gases rising from the fire. There is also a means of intercepting a portion of the escaping gases from the back of the bridge, with the object of burning them over again. This system was successful to some extent in diminishing the smoke, as may be gathered from a comparison of the smoke-scale when it was not in action with the smoke-scale when it was in action. It was tested on one of the boilers at the Royal Albert Hall.

No. 11. The Great Britain Smoke-consuming Company.—O. D. Orvis's system, in which air is introduced into the furnace above the fuel, through three tubes at the front, over the doorway. The outer ends of these tubes are directed downwards. A jet of steam at the bend of each tube is discharged through the horizontal limb into the furnace over the fire, so as to draw and drive currents of air into the fire amongst the smoke, with the object, at the same time, of accelerating the draught over the bridge. In burning slack, there was no evidence of efficiency for preventing smoke; in burning Welsh coal it appeared that the evaporative efficiency was increased by the employment of the apparatus. But as it did not appear to exercise any distinct influence for the promotion or the diminution of smoke, the favourable result can only be attributed to the mixing action of the steam-currents, effecting the combustion of carbonic-oxide, and augmenting the draught; and, in consequence, the more active combustion of fuel and the evaporation of more water. The apparatus was applied to a Cornish boiler constructed by Fraser & Fraser.

No. 12. W. A. Martin & Co.—This apparatus consists of a fire-door hung in the door-frame on pivots at the upper part, and balanced by counterweights, so as to remain at rest in any position. After a fresh charge of coal has been delivered, the door is swung open to a limited extent, easily determinable, so as to admit a wide and thin stream of air into the furnace, traversing the dead-plate, and flowing over the surface of the fire. The grate-bars consist of plain wrought-iron bars 1¼ inch square, which reach forward under the dead-plate, below which they are laid at a clear distance of 1¼ inch. By this arrangement an additional current of air is admitted below the dead-plate into the burning fuel. (Plate 52.)

The Martin door is fitted to the boilers at the Pumping Station, Brixton, of the Lambeth Waterworks. The trial boiler is 7 feet in diameter, and 28½ feet long, having two flues 33 inches in diameter. The grates were 5½ feet in clear length, having an area of 15 square feet each—together 30 square feet—for the 1st, 2nd, 3rd, and 4th trials, and were reduced to a length of 3 feet 9 inches, with a united area of 20·6 square feet, for the 5th trial. The steam was generated under atmospheric pressure.

These trials were made with a twofold object—to test the efficiency of the Martin door, and to test the comparative values of Nixon's Navigation coal and Northumberland steam coals. The combustion of the Northumberland coal is shown to have been accompanied by little more smoke than that of the Nixon's. The smoke-making quality of the North-country coal was tested in the course of the trial on January 19, when it was found that, keeping the doors closed, the smoke produced after firing lasted 9 minutes, against 2·20 minutes when the door was adjusted with a suitable extent of opening. The maximum smoke-shade was No. 9½ against No. 4, and the average shade was No. 7 against No. 2·20. This was evidence also of the efficiency of the Martin door for preventing smoke.

No. 13. A. C. Engert.—This apparatus, designed for a horizontal, under-fired, cylindrical boiler, consists of a shutter of two leaves in one casting, pivoted at the bend to the upper part of the furnace mouth. When the door is opened for charging, the incandescent fuel is pushed back upon the grate; after which the inner end of the shutter is lowered upon the fire, in order to prevent a rush of cold air into the furnace, whilst the fuel is charged partly on the dead-plate and partly on the fore part of the grate. When the door is closed, the shutter is raised a few inches off the fire, so that the gases distilled from the fresh coal, together with a stream of air admitted under the door, are passed close over the fire and burned together. The results of the 2nd and 3rd trials show almost entire prevention of smoke. The trials were made on the boiler at Mr. Engert's Compo Works, Three Mills Lane, Bromley-by-Bow, in which the grate was 7 feet long and 2½ feet wide. (Plate 53.)

No. 14. A. C. Engert.—This apparatus consists of two coking boxes, applied one to each side of a vertical boiler, for gradually coking and feeding the fuel into the furnace, by pushing it into the furnace. A small boiler of this description was tested at the Exhibition. The smoke was very slight, averaging No. 1 and No. 2 on the scale. (Plate 53.)

No. 15. J. Collinge.—Blocksage's apparatus, exhibited by Mr. Collinge, consists of an inclined grate and rectangular firebrick furnace for the combustion of the fuel, erected outside an internal-flue boiler, at the front. The products of combustion pass direct into the flue. This apparatus was tested as applied to a Cornish boiler, 5½ feet in diameter and 14 feet long, at Brick Lane Brickworks, Dukinfield. The grate was 2 feet 1 inch wide and 3½ feet long, with a supplementary grate at the lower end, making up a total length of 4 feet 11 inches and an area of 10¼ square feet. The door was kept close, but air was admitted to the fire through an opening under the dead-plate, 1½ inch deep, for the whole width of the grate. The brickwork was maintained at a white heat, and the result was an absolutely smokeless chimney.

No. 16. J. Farrar & Co.—Barber's stage-furnace exhibited is, like Blocksage's apparatus, constructed outside the boiler, at the front. It was tested on two Cornish boilers at the works of Mr. Farrar, Barnsley, 7 feet in diameter and 25 feet long, with 3½ feet flues. The furnace consists of three shelves 3½ feet wide, arranged one above another, 9 inches clear of each other. The uppermost shelf is the shortest, the one below it is longer than it, and the third is the longest. The three shelves thus form a sloping bearing for coal. They are supplemented by short grates reaching down from each shelf to within a few inches from the one below. At the lower end, a short grate is provided for the reception and removal of clinker and ash. The fuel used was hard smudge, a very fine slack; and, when the fire was made up, it became a sloping fire. The fuel was stoked on each shelf independently, and gently pressed inwards and under the incandescent fuel without breaking up the fire. The system of stoking was, in fact, under-feeding. The furnace was worked absolutely without any escape of smoke from the chimney. (Plate 54.)

No. 17. J. Wavish.—This system is applied to two Cornish boilers, 5 feet in diameter, 16 feet long, with a 33½-inch tube, at the Oil and Stearine Works, West Ham. It consists of a central water-tube, by which the furnace is divided into halves longitudinally: two level dead-plates, one on each side, extending the whole length of the furnace, and two upright grates, 9 inches high, 3 feet 5 inches long, one at each side of the water-tube, reaching from the tube to the dead-plates. The fuel is charged upon the dead-plates, piled half-way up the horizontal tube, and thus the vertical grates are covered by fuel. The in-draught sweeps through the grates across the fire. The result of the test was apparently complete combustion, with an entirely smokeless chimney,

in burning hard steam-coal. Hall's patent fuel was also tested, and the result, as indicated in the Table, was a nearly smokeless chimney. (Plate 55.)

Evaporative trials had been made on the boilers under notice by Mr. Felton, the manager, before the application of the Wavish system to them, and immediately after the application, in June 1879. The same coal was used in both these trials; it was of the same description as was used in the official tests. Each trial lasted 24 hours:—

	Coal	Water
Ordinary grate	65½ cwt.	4,643½ gallons
Wavish furnace	53¼ cwt.	5,039¼ gallons

Showing that about 20 per cent. less coal was consumed with the Wavish grate than with the ordinary grate, whilst 8 per cent. more water was evaporated.

No. 18. Livet's Patent Improved Boiler and Furnace Company.—The system of steam-boiler and furnace exhibited by this Company is described in the account of the boiler on the premises of Messrs. Clay, Sons & Taylor (page 134), which was employed for the testing of Welsh coals and anthracites. This system, though not professedly a smoke-preventer, possesses nevertheless a considerable degree of efficiency for preventing smoke. It is stated by Messrs. Tate & Sons, Sugar Refiners, Silvertown, that, according to their experience, the evaporative efficiency of their boilers, burning 6 cwt. of coal per hour per boiler, has been increased from 6·39 lbs. of water supplied at 66° F. per pound of coal, to 7·40 lbs., by the substitution of Mr. Livet's system of setting boilers. The results of performance of the testing boiler at Messrs. Clay & Co.'s, which has been at work on Mr. Livet's system for three years, are given in the Report (IX.) on Results of Tests of Fuels (page 136). (Plates 55, 56.)

No. 19. G. Haller & Co. exhibit Kohlhofer's fire-bars, which are constructed in short lengths of 9 inches. The bars are formed triangularly, in side elevation, with an opening in the middle for lightness. They are easily removed when required, and are not liable to suffer from excessive expansion. The results of the tests which were made at the works of Messrs. Stafford Allen & Co., City Road, London, show that more water was evaporated per pound of coal burned on these bars than on the previous grate of common bars. The old grate bars had been much worn away, and allowed, perhaps, an excess of air to pass into the fire, with waste of fuel falling through the grate, circumstances which may account for the difference. (Plate 57.)

No. 20. E. G. Wéry.—Wéry's apparatus, known as the Atmospheric Chimney, is designed to accelerate the combination of the atmospheric oxygen and unconsumed gases which rise from the fire at a high temperature. For this object, a winding or rotating movement is impressed upon the elements in the chimney, which, it appears, is extended to the body of gaseous elements in the furnace; so that in winding the gases spirally instead of ascending direct, more time is provided for mixing at a high temperature, and the mixture is better effected. This function is most simply exemplified in the case of vertical boilers having cylindrical iron chimneys. The tests were made on a vertical boiler having a fire-grate of five square feet in area. The lower part of the chimney was encased in a jacket for a height equal to three diameters. The external air was admitted into the jacket at the base, and in ascending it entered the chimney through two spiral slits $\frac{1}{16}$ inch wide at the base, gradually enlarging to $\frac{1}{8}$ inch in width at the top of the jacket, each slit making one revolution. The air entering through the slits mingled with and communicated a winding movement to the ascending hot gases, which appeared to be extended downwards by inducement to the body of gases in the fire-box, wherein, when the door was opened, the circling movement could be observed. It appears from the results of the tests, which were made repeatedly, that the evaporative efficiency of the same boiler was increased by more than one-half by the application of

this contrivance. From the results of independent trials made by M. Gibault, at Paris, in April 1880, it appears that while steam was got up in a portable boiler fitted with the Wéry chimney in 1 hour 18 minutes, with the ordinary chimney the time required to get up steam was 2 hours 2 minutes. (Plate 58.)

No. 21. J. M. STANLEY.—A furnace external to the boiler, in front of it, being an upright rectangular chamber or hopper of brickwork, filled with slack. The lower part is the furnace, in direct communication, by a short brick flue, with the flue of the boiler, into which all the products of combustion are discharged. It is perforated at the front wall for the admission of air in horizontal currents, which traverse the incandescent fuel, burn it, and pass through to the boiler-flue. This system was tested as applied to the Cornish boiler at the works of George Fletcher & Co., Poplar Iron Works. The boiler is 4 feet 7 inches in diameter, by 12 feet 4 inches long, with a flue 2 feet 6½ inches in diameter. The hopper is 3 feet wide by 10½ inches deep horizontally, and is 6 feet 7 inches high, inside the brickwork. There are two rows of openings 4½ inches square, four in each row, in the front face, through which air for combustion is admitted, subject to regulation by a slide. Air is supplied, when required, through an opening, controlled by a valve, in the lower side of the flue communicating to the boiler. Whilst the furnace continued in steady action, it was perfectly smokeless; but, in consequence, as it appeared, of the unsuitable form of the hopper, the fuel did not descend freely, and it was necessary to probe and drive it downwards from time to time, to supply the place of consumed fuel. On these occasions dense smoke was emitted; but this was promptly reduced when the air-valve at the back was opened.

No. 22. J. SMETHURST.—An apparatus for purifying smoke from steam-boilers. Shutting off the connection with the chimney, he diverts the products of combustion, by means of an exhausting rotary pump driven by the engine, through a cistern of water, where the black particles are precipitated, and also, it is said, the sulphurous acid; and whence the current is exhausted and is discharged through a pipe into the atmosphere. The smoke thus purified is of a light blue tint as it is discharged, and is free from depositable matter. Mr. Smethurst's apparatus comprised a small vertical boiler, 16 inches in diameter externally, lined with firebrick at the grate to form a furnace 7½ inches in diameter, in which the coal—hard steam—was burned. The vapours were discharged through a 6-inch pipe. By the result of a test, conducted for twenty minutes, it appears that coal was consumed at the rate of 23 lbs. per hour, and water was evaporated at the rate of 90 lbs., or about 1½ cubic foot, per hour; and that precipitating water was consumed at the rate of 27 cubic feet per hour, having been raised in temperature from 60° Fahr. to 130° Fahr.

REMARKS ON THE FIXED APPLIANCES.

The admission of air above and beyond the fire for the prevention of smoke is a well-known expedient, which has been adopted in various forms ever since the modern steam-engine was invented. It has, too, long been recognised that the heating of such extra supply of air prior to its emission into the furnace and flues, for the maintenance of a sufficiently high temperature during combustion, in conjunction with intimate intermixture, is of the first importance for the completion of the combustion of the gases discharged from the fire. The employment of means in various forms for effecting this object—the maintenance of a sufficiently high temperature—constitutes, accordingly, the chief speciality of the systems of smoke-prevention furnaces now exhibited.

MESSRS. CHUBB & Co. (No. 1) employ for this purpose a massive cast-iron bridge, exposed to the heat of the furnace, into the interior of which the supply of air is admitted, and from which the air is delivered in three thin sheets. The considerable

area of heating surface thus developed must operate beneficially in warming the air preparatory to its delivery above the bridge, further augmented as it is by the semi-circular projection of the bridge upwards, contracting the thoroughfare over the bridge to a semi-annular form; and not only augmenting the surface, but also insuring more immediate intermixture of the gases and the air. This upward semi-circular extension of the bridge is a notable feature of Chubb's system.

Mr. Gowthorpe (No. 2) has nevertheless succeeded in preventing smoke to at least as great a degree as Mr. Chubb, by projecting a single sheet of air horizontally from his cast-iron bridge. But it appears to be wanting in economy of fuel when the quantity of water evaporated per pound of coal did not exceed 3 lbs. Mr. Gowthorpe's system is also at least as effective for smoke-prevention as that of Mr. Hunter (No. 3), who has elaborated a double supply of air, the combustible gases passing between the under-current of air from the bridge, and the upper subdivided current from the arch beyond the bridge.

But Messrs. Ireland & Lownds (No. 4) effected a better contrast by their system of close-set iron pipes at the bridge, in which the air-supply was heated as it passed to the far end of the pipes, and was delivered in thin streams through grids. Comparing the action of this air-bridge with that of the ordinary bridge, it is seen that it reduced the maximum density of smoke from No. 10 on the smoke-scale to No. 4, and the average density from 6·75 to 2·0.

Mr. Pickering and Mr. Cornforth (Nos. 5 and 6) employ hollow fire-bars, through which air in passing to the bridge is heated. They did not make much reduction of the normal quantity of smoke. It is likely that in consequence of the frictional resistance to the passage of the air through the tubes, the supply of air was deficient; though, no doubt, the air that passed became highly heated.

Mr. Pickering's system, in its entirety, has, since the tests were made, been inspected in operation applied to inside fire-tube steam boilers at the Nubian Blacking Manufactory, Snow Hill, and at the Hackney Wick Confectionery Works; where it operated in preventing smoke, whilst the steam-pressure was maintained.

The results of the performances of Mr. Welton's asbestos grid (No. 7), behind the ordinary bridge, are interesting, but they are not conclusive. Undoubtedly, the efficiency of the fuel was augmented by the agency of the grid, under the special conditions of the boiler, which was not set in brick, and from the flue-tubes of which the gaseous products flashed direct to the chimney. But steam-boilers are not usually worked in this condition.

The systems (Nos. 8, 9, 10, 11) of Schmidt, Juillard, Elliott, and The Great Britain Company are all based on the long-known action of jets of steam in inducing currents of air to follow and accompany them. The air is thus blown over the surface of the fire, and its intermixture with the combustible gases and the consequent combustion are accelerated. None of these systems has, in the course of the tests, proved specially successful as a smoke-preventer; though M. Juillard's appeared upon the whole to be the most effective.

Messrs. Martin & Co.'s fire-door (No. 12) is tolerably effective as a smoke-preventer, of the simplest construction; adapted not only for stationary boilers, but also, being perfectly balanced, for marine boilers.

Mr. Engert's swing-shutter inside the furnace (No. 13) was, when carefully managed, entirely successful in preventing smoke for low rates of combustion. The average tints of smoke recorded in the Table are very light; and smoke was only emitted when the far end of the grate became uncovered and cold air was passed into the fire-place. It is apparent that the shutter interferes to some extent with the free play of the stoking implements.

Mr. Engert's system of coking-firing (No. 14), by a gradual feed of fuel, was very successful in preventing smoke. But it acted in this respect most efficiently when the

rate of combustion was lowest, as indicated in the Table: a rather inconvenient charac teristic, since it tends to impose a limit on the gross evaporative performance of any given boiler.

The BLOCKSAGE system (No. 15), of an external furnace in firebrick, and FARRAR'S system (No. 16), also external, and in firebrick, were both worked with facility and with success in exhibiting absolutely smokeless chimneys. They both depend upon the highly heated reverberatory surface of firebrick enclosing the burning fuel, for completely burning the fuel and preventing smoke: in heating the air and the gases that flow under the roof of the furnace, and maintaining the high temperature which is so conducive to completeness of combustion.

MR. WAVISH'S system (No. 17) is another of those in which the combustion of coal was complete, and the chimney was absolutely smokeless. It is distinct from the others which have just been referred to. The incoming air, sweeping horizontally the incandescent fuel, is highly heated, and carries with it highly heated gaseous products, all of which are mixed with, and so heat, the smoke-gases discharged from the comparatively fresh coal at the surface of the fire. In consequence, the mixture, having been detained at the surface of the fire by the horizontal sweep of the draught, is raised to a high temperature, which is maintained till combustion is completed. In testing the Wavish system with Weardale Steam Fuel, a light smoke was occasionally visible for a minute or two. The stoking of this furnace did not demand any special care on the part of the stoker. The means of actively circulating the water about the furnace have been found by the manager of the Oil and Stearine Works to be beneficial in the prevention of scale. Mr. Wavish's system is suitable for locomotives, as well as for marine-boilers.

In MR. LIVET'S system (No. 18) of setting boilers, it is not at first sight obvious that, by the employment of expanding flues of a special shape and construction, a materially better action of the furnace and boiler should be effected. It has, nevertheless, been ascertained by many instances of resetting on Mr. Livet's system, that the draught has been improved and the evaporative efficiency augmented. By referring to the tabulated results of the tests of Welsh coals (Table XXV.), it will be seen that, in the boiler at the works of Messrs. Clay, Sons & Taylor, which is set and fitted on Mr. Livet's principle, very high evaporative efficiencies of fuel have been attained. The large capacity of the flues, it may be added, affords exceptional facilities for inspection of the boiler.

The WÉRY system of atmospheric chimney (No. 20) merits a few words of special notice. The unexpected advantage gained by its employment on the vertical boiler exhibited is certainly a study for the mechanical philosopher.

MR. STANLEY'S hopper-system of external furnace (No. 21) is an exemplification of the system of gradual preparatory distillation of fuel as a means of preventing smoke. For the practical development of the system, action more nearly automatic is required for feeding down the fuel than the irregular action which now exists.

MR. SMETHURST'S Smoke-purifyer (No. 22) was effective in cleaning the smoke; but it is open to the objection that as much as eighteen times the quantity of water converted into steam was consumed in the operation. On a larger scale, probably, it would work more economically.

MECHANICAL STOKERS.

Mechanical stokers are divisible into two classes: those which operate by delivering the coal at the front, and coking it gradually as it is pushed backward on the fire-grate, and those which operate by spreading or scattering the fuel over the surface of the grate.

No. 23. THE PATENT STEAM BOILER COMPANY.—Knap's Mechanical Stoker (Class I.).—In this mechanical stoker, the hopper from which the fuel is fed, is provided with a slide, by which the supply to the crushing and feeding roller may be varied or entirely cut off. After passing the roller, the coal falls down an inclined plane to the front of the pusher, which delivers it on to the dead-plate, and thence to the fire-bars, five of which are movable and six are fixed. The movable bars are hooked at the front end and rest on a cross bar, to which a horizontal reciprocating motion and a slight vertical movement are given by a pair of side-levers working on a pivot. These levers also give motion to the pushers. The mechanism is simple and well arranged. (Plate 58.)

No. 24. GEORGE SINCLAIR (Class I.).—In this apparatus, the coal is fed into the furnace from a hopper, and the feed is varied by the adjustment of the stroke of the ram to from 1½ inches to 4 inches. The fire-bars are in five sections, each section consisting of three bars, of which the outer bars are flanged, and the centre bar is of the herring-bone form, interlocking with the inner edges of the outer bars of the section, which are similarly serrated. The far end of the centre bar is bevelled, and rises on a cross bearer as it is pushed back, so as to break up clinkers at the further end of the furnace. The motion of the fire-bars and the ram is taken from a five-throw crankshaft placed in front of the boiler, from each crank of which a short connecting-rod gives motion to a section of three bars. The shaft is driven by a spur-wheel and pinion, and a belt-pulley, and can be thrown out of gear by a clutch. The speed of the crankshaft is one revolution in 1¼ minute. The apparatus was tested at the Exhibition, on a Cornish boiler 5½ feet in diameter, 14 feet in length, with a flue tube 3 feet in diameter. The boiler was not set in brick, nor was it covered; and the burned gases passed direct through the tube to the chimney. (Plate 58.)

No. 25. KNOWLES & HALSTEAD.—'Holroyd-Smith's Helix Furnace Feeder' (Class I.).—The slack fuel from the hopper descends into a horizontal trough laid across the front of the boiler, at or about the level of the fire-door, in which it is traversed by means of a screw-movement. From this trough the fuel drops into three longitudinal troughs passing into the fire-place, and connected by perforated castings to form the grate. The fuel is moved by screws in these grooves into the fire-place, where it is at the same time lifted by the action of the screws and laid over the surface. The longitudinal screws are double-threaded, of from 8 inches to 10 inches in pitch, 5 inches in diameter at the front, and 2¼ inches at the far ends; and they are 4½ feet in length. They make one turn in 38 seconds. (Plate 59.)

No. 26. JAMES PROCTOR (Class II.).—In this mechanical stoker a single hopper is placed between the two flues of the boiler. A ram at the bottom of the hopper pushes the fuel alternately to the right and to the left, along two horizontal passages leading to a shovel-box at each end, facing the flues. From each box, a shovel, actuated by the release of a spiral spring, projects the coal into the furnace. The shovels are withdrawn to a different extent in each of three successive strokes by three cams giving a different degree of extension to the springs, thus imparting a different velocity of projection to the coal, and causing it to fall on a portion of the furnace varied for each of the three successive strokes. The springs can be adjusted to give the impulse required, and the impact of their recoil is softened by buffers. A flap-door is provided for hand-firing when required. The fire-bars are rocked by a hand-lever in front of the furnace. (Plate 60.)

According to a recent improvement, Mr. Proctor applies a motion for moving every alternate fire-bar. A crank-pin is fixed in a worm-wheel driven by a worm on the transverse shaft, by which two levers are moved up and down, from which, with a swivel-joint, a rocking shaft carrying the ends of the movable bars is worked. The movable bars rise and fall half an inch at the front; and at the far end they slide on a horizontal bearer. (Plates 61, 62.)

No. 27. JAMES NEWTON & SON (Class II.).—Small coal, or slack, from the hopper is dropped into a small receptacle over the door—near the roof of the door—from which it is propelled into the furnace by a blast of heated air, delivered at short intervals, from a pipe which traverses the flues of the boiler, and through which the air is driven by means of a fan. (Plate 63.)

T. & T. VICARS' Mechanical Stoker (Class I.): has been inspected at work. It is described in page 25.

The CHADDERTON IRONWORKS COMPANY'S (McDougall's) Mechanical Stoker (Class I.) also was inspected. It was tested in connection with the Manchester Smoke Abatement Exhibition, and a description with the results are given in the Report for that Exhibition. The chief peculiarity of this stoker consists in the motion for the fire-bars, which are controlled by an 'eccentricated shaft,' which carries their outer ends, and communicates a travel of ½ inch to and fro. (Plate 74.)

REMARKS ON THE MECHANICAL STOKERS.

It may be observed in the few results of tests given in Table XXV., that the only mechanical stoker which worked with complete smokelessness was the coking stoker of G. SINCLAIR (No. 24), tested at the Exhibition, on a Cornish boiler. As the experimental boiler was not set in brick, and as the products of combustion passed direct through the tube to the chimney, the rate of evaporation of water was comparatively low; but, for a flash flue, it was, under the circumstances, very effective.

THE PATENT STEAM BOILER COMPANY'S (Knap's) Stoker (No. 23) comes next in order of efficiency for prevention of smoke, but it showed a constant average smoke—No. 2 by the scale. It was tested at the Chalk Works, Grays, Essex.

KNOWLES & HALSTEAD'S (Holroyd-Smith's) Stoker (No. 25), tested at the printing works of Messrs. Unwin, near Ludgate Hill, showed still more smoke, due to the necessity for frequently levelling the fire, which was, in consequence of the mode of feeding back the fuel by isolated propelling screws, raised into ridges.

JAMES PROCTOR'S Shovel Stoker (No. 26), tested at Heyworth's Weaving Shed, Blackburn, showed an average light, though continuous, smoke, which was less than half of what was produced in hand-firing.

J. NEWTON & SON'S Stoker (No. 27) was tested at New Royd Mills, Oldham. The test-boiler was one of three in a line; and as the fan was not powerful enough to supply all the three boilers at once, one of the three was fired by hand. It was, in consequence, nearly impracticable to distinguish accurately the discharge of such smoke from the chimney as might have arisen from the test-boiler. The smoke was, so far as was observed, very light in shade. There was 10 per cent. greater evaporative efficiency by the use of the mechanical stoker, compared with hand-firing. This result is corroborative of the report of the Chief Engineer of the National Boiler Insurance Company, by whom the boiler had previously been tested.

Of the systems of Mechanical Stokers which have been tested, as above recorded, that of G. SINCLAIR (No. 24) was the steadiest in action, and was the only one which was worked without the interference or the occasional aid of the shovel or the rake. The excellence of the stoker was also proved by the complete absence of smoke, already noticed, and by the efficient manner in which it transported and rejected the heavy masses of clinker that were formed.

D. K. CLARK.

VIII. REPORT ON TESTS OF GAS ENGINES.

Two tests of Gas Engines were made,—Otto Silent Gas Engines, in both instances. One test was made of the 2 horse-power Otto Engine, exhibited by Crossley Brothers, consuming coal-gas. The other test was made of a 3½ horse-power Otto Engine, exhibited by the Dowson Economic Gas Company, consuming the Dowson Cheap Gas. This gas forms the subject of a special report (page 112), in which the results of the test as a motive power have already been communicated.

The Otto Silent Gas Engine, of 2 horse-power (plate 66), exhibited by Crossley Brothers, is a 'half single-acting engine,' horizontal, in which the motive power is exerted only on one face of the piston, of which the other face is open to the atmosphere; and is exerted at every alternate stroke only. The cylinder is $5\frac{11}{16}$ inches in diameter, with a stroke of 12 inches. The piston is 8 inches in length, and the engine makes, at the regular speed, 160 revolutions of the crank-shaft per minute. The cylinder is water-jacketed, to keep down the temperature; although it is estimated that a loss of 42 per cent. is thus incurred. A mixture of air and gas, in the proportion of 16 to 1, is adopted, in order to ensure slowness of combustion, with, in consequence, a deliberate and continuous pressure on the piston during the stroke, analogous to that of an expansive-working steam engine. The cylinder is filled during alternate strokes with the mixture. On the return stroke, the mixture just admitted is compressed until it reaches a pressure of 35 lbs. per square inch. At this pressure, the mixture explodes, and, to ignite it, a strong mixture is provided at the touch-hole. The mixture continues burning throughout the following stroke. For both heavy and light duty, the explosive mixture is of the same proportions. But, for light work, the engine may miss two or more strokes without an explosion taking place, according to the work to be done. The frequency of explosions is regulated by means of a simple governor. The engine was tested on a friction-brake, by means of an indicator connected to the end of the cylinder, during a period of 40 minutes, when six indicator-diagrams were taken from it. The initial pressure in the cylinder varied from 112 lbs. to 130 lbs. per square inch above the atmosphere pressure. The pressure on exhausting, near the end of the stroke, was about 28 lbs. per square inch. The speed averaged 156·4 revolutions per minute, making 78·2 explosions per minute. The effective mean pressure on the piston was 62·74 lbs. per square inch. The area of the piston was 25·41 square inches. The length of the stroke being 1 foot, the power of the engine was equal to $(25{\cdot}41 \times 62{\cdot}74 \times 1 \times 78{\cdot}2 \div 33{,}000 =)$ 3·78 indicator horse-power. Gas was consumed at the rate of 100 cubic feet per hour, equivalent to $(100 \div 3{\cdot}78 =)$ 26·45 cubic feet per indicator horse-power per hour. Taking the number of explosions per hour equal to $(78{\cdot}2 \times 60 =)$ 4,692 explosions, the quantity of gas consumed for each explosion was $(100 \times 1{,}728 \div 4{,}692 =)$ 36·8 cubic inches, or $\frac{1}{47}$ cubic foot. It is stated by the exhibitors that the engine had not previously consumed more than $\frac{1}{52}$ cubic foot of gas per charge. A leakage may possibly have existed in the connections whilst the engine was under test.

The results of performance of the Dowson cheap gas in the 3½ horse-power Otto Engine may here be recapitulated. The average speed was 156 revolutions per minute, making 78 explosions per minute. The indicator power was 4·41 horse-power; and 110·34 cubic feet of gas were consumed per horse-power per hour.

It appears that, of the Dowson gas, 4·17 times the volume of coal gas was consumed per horse-power per hour. Taking the respective costs per 1,000 cubic feet at 4*d.* and 3*s.*, or as 1 to 9, the relative costs per horse-power are as 4·17 to 9, showing that the Dowson gas does the same work for less than half the money.

Clerk's gas engine, though it was not tested, may be briefly described. It was a single-acting engine, of 2 horse-power, having a 4-inch cylinder, with a stroke of 8 inches, and making 200 revolutions per minute. An explosion takes place at every out-stroke, the mixture of gas adopted being 9 of air to 1 of gas, admitted for the first half of the stroke. During the second half-stroke, pure air is admitted. In order to effect the explosion at every out-stroke, a displacer-cylinder is employed. The charge is compressed till a pressure of 38 lbs. per square inch is attained, when it is exploded and burns during the out-stroke. The exhaust takes place near the end of the stroke, and as the piston returns, the pure air of the charge is exhausted through the pipe, which is cooled.

D. K. CLARK.

IX. REPORT ON TESTS OF FUELS.

TWENTY-NINE varieties of anthracites and Welsh coals, with three samples of Newcastle coals, and three samples of artificial, or so-called patent, fuels, were submitted to be tested. The tests were distributed as follows:—

Fuels	Number of fuels	Number of tests
Anthracites	16	18
Welsh steam coals. . . .	13	20
Northumberland steam coals .	3	4
Artificial fuels	3	3
Totals	35	45

The steam boiler in daily operation at the printing works of Messrs. R. Clay, Sons & Taylor, Bread Street Hill, Queen Victoria Street, London, was, with the permission of the proprietors, selected to be the testing boiler. It was started at work on September 1, 1879, and was illustrated and described in 'The Engineer,' May 28, 1880. It is of the Lancashire or double flue-tube type. The shell is 7 feet in diameter, and 18 feet in length; the two flues are 2 feet 9 inches in diameter at the furnace, and reduced conically to a diameter of 2 feet 4 inches at the far end. There are two characteristic features in the plan of this boiler—the invention of Mr. Fountain Livet. One feature is the form of the seating and the proportioning of the flues. The boiler is set upon two cast-iron stools, extending between which a central partition wall is built, finished with a course of bull-nose bricks, which are in contact with the lower side of the boiler, though they do not take any of the load. The flues, right and left, with a winding draught, are made successively larger in sectional area as they advance from the fire-tubes. That is to say, the first external flue, leading to the front, is larger in sectional area than the internal flue-tubes taken together; and the second external flue, leading from the front to the back, at the other side of the boiler, is larger than the first flue. The chimney, likewise, is formed with an expanding sectional area towards the top. Two capacious pits are constructed, one at each end of the boiler, for the collection of dust and soot. The second special feature is the fire-grate; the fire-bars are made of great depth—about 12 inches—and of a long wedge-formed section, so as to facilitate the in-draught of air into the fire, and to warm it as it ascends. That they may not be subject to breakage by unequal expansion, the fire-bars are constructed in two parts, upper and lower, longitudinally fitting together to form one bar. Mr. Livet shows that, by the adoption of such arrangements, the draught is improved, and a greater proportion of heat is absorbed by the boiler, in consequence of the diminishing velocity of the current, as compared with the velocity in a system of flues of uniform area of section. (Plates 55, 56.)

The fire-grates are 22 inches in width, being 11 inches narrower than the fire-place. The dead-spaces at the sides are filled with cast-iron plates. The grates are 5 feet in length, and have together a working area of $18\frac{1}{3}$ square feet. The fire-bars are made in two lengths, and there are 15 in the width. They are $1\frac{1}{4}$ inch in thickness at the dead-plate, and $1\frac{3}{8}$ inch at the bridge, with air-spaces averaging $\frac{5}{16}$ inch wide. The

fire-bars are from 10 inches deep at the front to 12 inches deep at the back; they are flat at the top, and grooved.

The boiler is coated with Leroy's composition, 3 inches in thickness. The boiler was fed with New River water, which under ordinary conditions deposits a hard scale. But the formation of scale was here prevented by the use of plates of zinc suspended within the boiler. Mud and sand were deposited at the bottom. The boiler is, in ordinary practice, cleaned out every three months. As the tests were carried on over a long period of time—upwards of three months—samples of steam from the boiler were tested from time to time for priming water in mixture with the steam. The results of these tests proved that there was little or no priming in the steam. For instance, on the 22nd and 23rd December 1881, just before the boiler was washed out, the results of four tests showed an average of less than 1¼ per cent. of the whole water supplied as priming, thus:—

Dec. 22, 1881	Priming	1·60	per cent.
„ 22, „	„	1·33	„
„ 23, „	„	0·00	„
„ 23, „	„	2·00	„
Average		1·23	„

On another occasion—in March 1882—within a week after the boiler was cleaned out, the results of two tests were as follows:—

March 31, 1882	Priming	1·39	per cent.
„ „	„	0·00	„
Mean		0·70	„

In view of these evidences of the general purity of the steam, it may be assumed that the tests of fuels were worked under uniform conditions of the boiler.

Each test was completed in one day, lasting usually for periods of from 7½ hours to 8 hours. The feed-water was measured from a large rectangular tank, where the temperatures at the beginning and the end of the experiment were taken. The coal was weighed out 1 cwt. or 2 cwt. at a time, and broken into manageable pieces which were usually charged into both fires, ½ cwt. to each, one after the other. Occasionally, 2 cwt. was charged at a time, in the case of anthracites; and occasionally the firing was alternate. Before the trial was commenced, the fires were allowed to burn down until they were ready for fresh stoking. The levels and condition of the fires were noted, together with the level of the water in the boiler; also the time; then the trial was held to commence, and a charge of coal was delivered. Towards the end of the period of trial, the fires were again let down until they were ready for fresh stoking, care being taken that they should be, as nearly as could be ascertained, in the same condition as at the commencement, also that the water-level in the boiler was the same as at the commencement. The trial was then held to have terminated. The time was noted; the unconsumed coal that was weighed out, if any was left, was weighed back; the clinker was cleared from the grate, and both it and the ash from the ash-pit were weighed. The level of the water in the tanks was again measured, and the fall of level and the quantity consumed were determined. The temperature of the burnt gases as they passed away to the chimney was gauged at short intervals by means of a pyrometer. The smoke-shade at the chimney-top was noted. The standard working pressure was that of 60 lbs. per square inch at the safety-valve.

Six of the tests were made with one of the steam boilers at the Brixton Pumping Station of the Lambeth Waterworks, fitted with the fire-doors of W. A. Martin & Co. The ostensible purpose of these tests was the testing of the fire-doors; and, incidentally, the occasion was improved for the purpose of, at the same time, testing the steam coals consumed. The boiler is described in the notice of the tests of the Martin doors (p. 124).

One test was made in conjunction with the test of J. Wavish's upright fire-grates, in a Lancashire boiler, at the works of the Oil and Stearine Company, West Ham, noticed in the Report on Steam Boiler Appliances (p. 125).

The leading results of the tests of coals are stated in Table XXVI. The tests of anthracites and Welsh steam coals, Nos. 1 to 37, and tests Nos. 43 and 44 of two artificial fuels, were made with the testing boiler at Clay & Co.'s printing works. The five tests Nos. 38 to 43 were made at Brixton Pumping Station, and the last test, No. 45, was made at West Ham.

The anthracites of the Anthracite Coal Company were, in general, rough of fracture, and friable. The most efficient of them for the ratio of the evaporated water to the fuel, according to column 16 of the Table, was No. 7, the Brass Vein anthracite, from Ystradgunlais, by which 14·23 lbs. of water was evaporated per lb. of fuel from and at 212° F. At the end of the eight hours' trial, there was but little clinker and ash, and the clinker did not adhere to the fire-bars. This anthracite proved, in fact, to be one of the best of all the samples that were tested, in combining evaporative efficiency with maintenance of pressure and ease of stoking. Nos. 8 and 10, anthracites, from the 4-feet Vein of Evans and Bevan, proved to be the poorest of all the anthracites that were tested: the steam pressure could not be maintained, as the grate was encumbered with ash and clinker, which required to be frequently sliced, although it parted without difficulty from the bars.

The Cawdor anthracite, No. 15, swelled to a small extent in the furnace—an indication probably of a slightly bituminous nature,—though it was entirely smokeless.

The Dynant anthracite, No. 16, was hard, and it broke with a clean fracture. It burned brightly and evenly, with a strong heat. The damper was fixed at 'half-open,' and it remained in this position during the test. The clinker was easily sliced off.

The Trimsaran samples, Nos. 17 and 18, from the 9-feet Vein and the 4-feet Vein of the Gwendreath Valley, behaved differently. No. 17 yielded more heat and evaporated more water than No. 18, but it burned less freely.

TABLE XXVI.—RESULTS OF TESTS OF ANTHRACITES

No. of test	Name of exhibitor	Date of trial	Time under trial	Coal Consumed			
				Exhibitors' description	Total consumed	Per hour	Per square foot of grate per hour
1	2	3	4	5	6	7	8
	ANTHRACITES (CLAY & CO.'S BOILER).	1881	h. m.		cwts.	lbs.	lbs.
1	The Anthracite Coal Company .	Sept. 28	8 0	4-feet Vein, Ystradgunlais . .	13	182	9·93
2	Do. do. .	„ 29	7 41	White Vein, Ystradgunlais . .	15	218·2	11·90
3	Do. do. .	„ 30	7 15	9-feet Vein (Evans and Bevan) .	11	170	9·27
4	Do. do. .	Oct. 3	8 5	Peacock Vein, Gwann-Cae-Gurwen .	12	168	9·17
5	Do. do. .	„ 4	7 30	Black Vein, Ystradgunlais . .	12½	187	10·20
6	Do. do. .	„ 5	7 40	Big Vein, Gwann-Cae-Gurwen . .	13	191	10·40
7	Do. do. .	„ 6	7 30	Brass Vein, Ystradgunlais . .	11	164·3	8·96
8	Do. do. .	„ 11	7 20	4-feet Vein (Evans and Bevan) .	15	229	12·50
10	Do. do. .	Nov. 10	7 40	4-feet Vein (Evans and Bevan) .	14·68	214	11·69
14	Do. do. .	Dec. 16	7 50	Big Vein, Amman Valley . . .	14	200	10·92
9	Do. do. .	Oct. 27	7 50	Glynmoch	14	200	10·92
11	Do. do. .	Dec. 5	8 0	9-feet Vein, Maesymarchog . .	12	168	9·16
12	Do. do. .	„ 12	8 0	Timber Vein, Swansea Valley . .	12¼	175	9·55
13	Do. do. .	„ 14	7 50	Red Vein, Amman Valley . . .	13	186	10·15
15	The Cawdor Colliery Company .	Oct. 17	7 30	Cawdor Colliery	13	194	10·59

Beginning with the first of the Welsh coals, No. 19, Graigola coal, was one of a series of five coals exhibited by Cory, Yeo & Co. It was a hot-burning coal, expanding quickly as it became heated, and burning off quickly. It was very friable—the only sample that was very friable,—and it would have better suited an easier draught. No. 20, Graig Merthyr, was a very hard coal, which lay as it opened, without any enlargement of volume. No. 21, Clydach Merthyr, burned much more freely than the two preceding samples. No. 22, Velindre Merthyr (Birch Rock), is a hard coal, and burns like anthracite, rather dark on the top. No. 23, Hill's Merthyr, was the last of this series. Nos. 20, 22, and 23 were the hardest, and were preferred to many other samples.

No. 24, Mardy, 4-feet Seam, is a very hard coal. It burned solidly and it did not swell at all. It approached the strongest anthracite in hardness. Incandescent lumps broken in the fire showed black in the interior.

No. 25, Joseph's Dunraven Merthyr, is a coal of good quality. It breaks softly, and it opens up in the fire like a cauliflower.

No. 26, Llest coal, is a free-burning coal. No. 27, Cwmaman, burned like the Mardy sample, fiercely but slowly, showing black inside when broken in the fire. It delivered much flame and heat immediately after a firing.

Several private tests, Nos. 28 to 35, of Aberdare Rhondda steam coal, the fuel usually consumed at Clay & Co.'s printing works, have been included in the Table. They were made with a view to testing the comparative evaporative efficiency of the boiler in its varying conditions of cleanness or muddiness. The first sample, No. 28, was the sample supplied direct by the Company for an official test. No. 29 test was made at an early date, for the special purpose of testing Mr. Livet's system, on which the boiler was set and fitted. In this instance, as in all the tests that followed—Nos. 30 to 35—the samples were taken as required direct from the coal-heap in the boiler-shed. The maximum of evaporative efficiency, attained in No. 29 test, was probably achieved by special attention to the damper, keeping it nearly close during the time the doors were open for stoking. The last of the series, No. 35, was made with coal consisting in great portion of small

AND WELSH STEAM COALS.

No. of test	Refuse				Water Evaporated					Smoke, by Smoke-Scale					Average pressure of steam per square inch	Average temperature in departing flue
								Per lb. of coal					Average length of time			
	Clinker	Ash	Total	Per cent. of coal	Temperature	Total	Per hour	Actual	From and at 212°	Maximum density	Average density	Average duration for one firing	Visible	No smoke		
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	lbs.	lbs.	lbs.	per ct.	deg. F.	cub. ft.	cub. ft.	lbs.	lbs.	No.	No.	min.	per cent.	per cent.	lbs.	deg. F.
1	16	21	37	2·54	61°	189·86	23·73	8·13	9·59	.	.	. Smokeless	.	. .	60·0	—
2	42	53	95	5·65	61	188·33	24·46	6·99	8·25	.	.	. Smokeless	.	. .	57·0	—
3	30	19	49	4·00	59	170·50	22·73	8·34	9·84	.	.	. Smokeless	.	. .	59·0	—
4	—	—	—	—	57	191·00	24·00	8·87	10·57	.	.	. Smokeless	.	. .	59·0	—
5	13	38	51	3·64	56	183·40	24·40	8·18	9·65	.	.	. Smokeless	.	. .	58·8	382·6
6	23	75	98	6·73	53	193·10	25·37	10·87	13·01	.	.	. Smokeless	.	. .	57·0	352·2
7	13	32	45	3·65	51	176·10	23·50	11·89	14·23	.	.	. Smokeless	.	. .	60·2	303·1
8	51	62	113	6·73	58	184·10	25·10	6·84	8·11	.	.	. Smokeless	.	. .	51·0	398·9
10	88	136*	224	13·62	56	181·60	23·68	6·89	8·17	.	.	. Smokeless	.	. .	40·5	457·4
14	32	45	77	4·91	49	184·80	23·60	7·35	8·72	.	.	. Smokeless	.	. .	56·8	409·7
9	28	52	80	5·10	55	181·90	23·23	9·25	10·96	.	.	. Smokeless	.	. .	49·0	388·5
11	11½	63	74½	5·54	49	176·60	22·10	8·20	9·76	.	.	. Smokeless	.	. .	61·0	336·5
12	6	39	45	3·21	52	184·80	23·10	8·24	9·85	.	.	. Smokeless	.	. .	60·3	366·0
13	8½	36	44½	3·06	48	184·30	23·54	7·90	9·45	.	.	. Smokeless	.	. .	58·8	357·1
15	3	52	55	3·77	57	196·50	26·20	8·42	9·98	.	.	. Smokeless	.	. .	49·1	367·4

TABLE XXVI.—RESULTS OF TESTS OF ANTHRACITES

No. of test	Name of exhibitor	Date of trial	Time under trial		Coal Consumed			
					Exhibitors' description	Total consumed	Per hour	Per square foot of grate per hour
1	2	3	4		5	6	7	8
		1881	h.	m.		cwts.	lbs.	lbs.
	ANTHRACITES (CLAY & Co.'s BOILER (*cont.*).							
16	The Dynant Colliery Company.	Nov. 9	7	55	Stanllyd Vein	14	198	10·80
17	The Trimsaran Colliery Company	„ 23	7	55	9-feet Vein, Gwendreath Valley .	11	156	8·49
18	Do. do. .	„ 25	8	0	4-feet Vein, Gwendreath Valley .	12	168	9·16
	WELSH STEAM COALS (CLAY & Co.'s BOILER).							
19 [1]	Graigola Merthyr (Compagnie Houillère de), Cory, Yeo & Co.	Nov. 3	5	15	Graigola	11	235	12·86
20 [2]	Do. do. .	Oct. 19	6	15	Graig Merthyr	10	179	9·78
21	Do. do. .	„ 20	6	20	Clydach Merthyr	12·87	228	12·42
22 [3]	Do. do. .	„ 31	6	15	Velindre Merthyr (Birch Rock) .	10	179	9·78
23	Do. do. .	„ 18	7	15	Hill's Merthyr	13	201	10·95
24	Locket's Merthyr Steam Coal Company	Nov. 7	8	0	Mardy, 4-feet Seam, Little Rhondda	12	168	9·16
25	The Dunraven Colliery . .	„ 15	8	12	Joseph's Dunraven Merthyr . .	10	137	7·45
26	The Cwmaman Coal Company.	„	7	7	Llest, No. 3 Rhondda Vein . .	12	189	10·38
27	Do. do. .	„	8	0	Cwmaman, Upper 4-feet Seam .	10	140	7·64
28	Aberdare Rhondda Steam Coal Company	Dec. 6	8	5	Aberdare Rhondda	9	126	6·87
29	Do. Special trial of Livet's system on the same boiler . .	Sept. 22	6	13	Do. do.	7·44	134	7·31
30	Private trial	Nov. 21	6	35	Do. do.	9	160	8·73
31 [4]	Do.	„ 22	7	50	Do. do.	8½	122	6·63
32	Do.	„ 24	7	45	Do. do.	9	130	7·09
33	Do.	Dec. 2	8	5	Do. do.	10	140	7·64
34	Do. . . .	1882 April 6	7	45	Do. do.	13	188	10·26
35	Do.	1881 Nov. 28	7	50	Do. do. small and slack .	12	172	9·36
36	Williams & Co.	Dec. 21	7	50	Duffryn Aberdare	12	172	9·36
37	Do.	1882 Mar. 30	8	5	Lewis's Navigation	13	182	9·93
	NIXON'S NAVIGATION & NORTHUMBERLAND STEAM COALS (BRIXTON PUMPING STATION).							
38	Private	Jan. 18	6	0	Nixon's Navigation steam coal . .	19	355	11·82
39	North of England Coal Trade .	„ 19	4	18	Northumberland steam coal . .	18	502	16·73
40	Do. do. .	„ 20	5	5	Do. do washed small coal	26½	584	19·50
41	Do. do. .	„ 21	5	10	Do. do. rough small	23	495	16·50
42	Do. do. reduced grate . . .	„ 17	4	10	Northumberland steam coal . .	16	430	20·87
	ARTIFICIAL FUELS (CLAY & Co.'s BOILER, &c.).							
43	Cory, Yeo & Co. . . .	1881 Oct. 21	7	35	Graigola Merthyr patent fuel . .	14	206	11·26
44	Edford Colliery Company .	Nov. 8	8	0	Patent Sanitary fuel	15	210	11·46
45	J. Hall, junr. & Co. . . .	Oct. 12	5	0	Weardale Steam fuel. . . .	8·19	183	17·90

[1] Engine stopped for 20 minutes to cool bearings.

[2] Engine stopped three times for 1 hour 20 minutes.

AND WELSH STEAM COALS—(*continued*).

No. of test	Refuse				Water Evaporated					Smoke, by Smoke-Scale.					Average pressure of steam per square inch	Average temperature in departing flue
	Clinker	Ash	Total	Per cent. of coal	Temperature	Total	Per Hour	Per lb. of coal: Actual	Per lb. of coal: From and at 212°	Maximum density	Average density	Average duration for one firing	Average length of time: Visible	Average length of time: No smoke		
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	lbs.	lbs.	lbs.	per ct.	deg. F.	cub. ft.	cub. ft.	lbs.	lbs.	No.	No.	min.	per cent.	per cent.	lbs.	deg. F.
16	32	54	86	5·49	56	197·90	24·99	9·94	11·84	Makes a little smoke, barely perceptible, for a few minutes after firing					53·4	439·7
17	10½	59	69½	5·64	56	165·20	20·85	8·37	9·97	Smokeless					58·1	325·6
18	9	59	68¾	5·06	55	163·0	20·40	7·57	9·01	Smokeless					57·6	330·7
19[1]	0½	46	46½	3·79	50	135·80	25·87	6·88	8·22	3	1·5	2	5·0	95·0	52·4	403·9
20[2]	3	49	52	4·64	55	134·60	21·50	7·50	8·89	1	0·5	1	1·7	98·3	51·6	320·0
21	0	47	47	3·25	52	168·10	26·55	7·28	8·63	2½	1·0	1	1·7	98·3	51·0	369·2
22[3]	3	42	45	4·04	53	127·30	20·37	7·09	8·41	1	0·5	1	1·7	98·3	56·1	289·4
23	0	48	48	3·30	55	226·0	31·20	9·69	11·91	2	0·75	1¼	2·1	97·9	57·0	340·8
24	2	31	33	2·46	60	204·40	25·55	9·49	11·33	3	1·0	2½	4·2	95·8	54·7	380·5
25	2½	33	35½	3·17	60	197·20	24·04	10·99	13·06	3	1·3	1¼	2·2	97·8	59·8	297·8
26	1½	29	30½	2·27	50	190·60	26·77	8·85	10·49	6	2·7	2¼	5·6	94·4	54·8	417·3
27	21	27	48	4·23	59	214·60	26·80	11·91	14·21	3	1·3	1	1·7	98·3	60·5	353·0
28	9	45	54	5·35	52	176·50	22·06	10·93	13·07	Smokeless					57·1	318·2
29	0	20	20	2·40	60	163·70	26·30	12·25	14·53	Smokeless					61·0	—
30	3½	50	53½	5·31	59	170·20	27·02	10·54	12·49	Smokeless					59·0	292·3
31[4]	4½	44	48½	5·09	57	171·70	21·93	11·25	13·46	2	1·0	1	1·7	98·3	58·4	287·7
32	12½	53	65½	6·51	56	176·80	22·81	10·95	12·79						58·6	294·8
33	13	26	39	3·48	52½	163·10	20·40	9·09	10·84	Smokeless					53·6	338·5
34	23¼	42	65¼	4·49	57	199·70	25·77	8·56	10·24	Smokeless					54·6	313·1
35	15½	71	86½	6·44	55	167·40	21·39	7·78	9·30						56·0	335·7
36	2	49	51	3·79	49	192·80	24·63	8·95	10·66	3	1·3	1	2·2	97·8	52·7	335·8
37	15¾	49	64¾	4·45	55	178·30	22·30	7·64	9·06	3·5	1·4	4	10·0	90·0	53·5	324·2
38	42	85	127	5·97	83	400	66·70	11·69	13·25	3	1·2	1·00	6	94	Atmos.	500 +
39	42	34	76	3·77	92	353	82·10	10·87	12·22	4	2·2	2·20	13	87	Atmos.	612 +
40	88	36	124	4·17	89	409	80·50	8·56	9·65	2	0·75	1·00	3	97	Atmos.	612 +
41	250	156	406	15·80	93	369	71·0	8·90	10·0	2	0·90	1·01	9	91	Atmos.	—
42	62	33	95	5·30	84	321	77·0	11·14	12·62	4	1·80	3·70	24	76	Atmos.	612 +
43	4	38	42	2·67	53	178·30	23·46	7·09	8·41	3	1·20	1·62	5·4	94·6	50·06	395·3
44	nil	150	150	3·93	57	201·50	25·20	7·49	8·88	6	3·10	1·25	4	95·8	48·54	409·6
45	—	—	—	—	122	118·80	23·40	7·87	8·77	4	1·80	2·25	18	82	35·00	—

[3] Engine stopped 1 hour 5 minutes.

[4] Engine stopped for a few minutes.

coal and slack. The evaporative efficiency, in this instance, was decidedly less than that of the samples of ronnd coal in the series.

No. 28 sample, Aberdare Rhondda, though not hard, yet burned slowly and thoroughly, leaving a fine light-coloured ash. The flame was bright and white.

No. 34 sample gave a moderately long white flame, with considerable heat. A small proportion of small coal and slack was in mixture.

No. 36, Duffryn Aberdare, was a friable sample. It burned freely, making a short white flame. It swelled in burning, and appeared to collapse when tonched.

No. 37, Lewis's Navigation, burned rather quickly, with a short yellowish-white flame.

The tests, Nos. 38 to 42, of Northumberland steam coal and Nixon's Navigation coal, made with the Lancashire boiler at Brixton Pumping Station, were conducted on the same lines as those which were made with the testing boiler at Bread Street Hill, with the exception that the testing boiler at Brixton was isolated from the others in the range, and the generated steam was blown off direct into the atmosphere, at atmospheric pressure. The temperatures in the flue (colnmn 24 in the Table) were proved approximately by the melting and the non-melting of pieces of metals. For the last test of Northumberland coal, No. 42, the fire-grate was shortened from 6 feet in length to $3\frac{3}{4}$ feet; the area was correspondingly reduced.

The fires were maintained at a uniform thickness of 6 inches with the longer grate, and 8 inches with the shorter grate; and they were stoked at intervals of from 15 to 30 minutes for Nixon's coal, and 15 minutes for the Northumberland coal. Each charge weighed about half a hundredweight.

Of the artificial fuels tested, Graigola Merthyr fuel, No. 43, is of the usual composition of slack and pitch. The Sanitary fuel, No. 44, consists of 10 parts of slack to 1 part of slaked lime. The lime is the cement, as well as the purifying agent, in combining with and detaining sulphur and ammonia. The Sanitary fuel burns with a bright white flame, without great heat. It takes fire readily, and lies quietly on the grate. The large proportion of lime disengaged as ash did not involve any unusual degree of attention to the fire, to keep the bars clear of lime. The steam was kept up, and there was no clinker. The Weardale Steam fuel, No. 45, in blocks weighing $18\frac{1}{4}$ lbs. each, is composed of the finest North-country coal-dust and 8 per cent. of pitch. It did not demand any special care in firing, and the steam was well maintained.

DEDUCTIONS.

Tonching the relative behaviour of the anthracites and Welsh coals, Nos. 1 to 37 in the Table, steam was kept up equally well and conveniently with the two classes of fuel, for the periods of trial. But, for prolonged work, the labour of picking and cleaning the fire in burning the anthracites was in general greater than for the Welsh steam coals. The clinker of the anthracites was usually deposited on the fire-bars as a thin layer, like a pouring of melted metal, which the slicer could not touch. After some hours of continuous work, the fire-bars, especially about the mid-length of the furnace, became red-hot, and the draught was weakened. In burning Welsh coals, on the contrary, the fire-bars remained black, indicating the maintenance of a free draught; and clinker, when formed, was easily separated. With Welsh coals, steam was got up on Monday mornings in three-quarters of an hour, and on other mornings in half an hour. Twice these lengths of time were required for getting up steam with the anthracites. The greater length of time required by anthracite fuel is readily accounted for by its characteristically short and evanescent flame, by which but a small proportion of heat is carried.

In conclusion, on the Clay boiler tests, it may be remarked that the fuel which may

give the greatest degree of satisfaction to the intelligent stoker, is not necessarily the most efficient for evaporation. A stoker places a high value on handiness, free-burning, scarcity of clinker and ash, and on clinker, if there be clinker, that does not cling. For these reasons, the Welsh steam coals, as a class, are preferred to the anthracites.

Of steam coals, the Velindre Merthyr (Birch Rock), No. 22, the Mardy 4-feet Seam, No. 24, and the Cwmaman Upper 4-feet Seam, No. 27, may be classed together as fuels which unite in a high degree the qualities which are sought for by stokers; and, of these, the Cwmaman coal exhibited the greatest evaporative efficiency.

Of the anthracites, the Brass Vein, Ystradgunlais, developed, as an anthracite, the highest efficiency. It was not exceeded by any Welsh coal in efficiency, if the rather exceptional test, No. 29, be omitted from the comparison. The sample of Dynant anthracite, No. 16, ranked third in evaporative efficiency amongst the anthracites; but it was probably, taken all round, the best sample of anthracite that was tested, combining a high rate of evaporative efficiency with easy manipulation.

The four best samples of maximum efficiency, noticed above, are here placed together, with their respective evaporative efficiencies:—

	From and at 212° F.
No. 24. Mardy, Welsh steam coal . . .	11·33 lbs. water per lb. of fuel
No. 27. Cwmaman, Welsh steam coal . .	14·21 lbs. " "
No. 7. Brass Vein, Ystradgunlais, anthracite .	14·23 lbs. " "
No. 16. Dynant, anthracite	11·84 lbs. " "

To form a general comparison of the fuels on the whole body of evidence, the leading results of all the tests of steam coals and anthracites are embraced in Table XXVII.

TABLE XXVII.—SUMMARY RESULTS OF TESTS OF WELSH STEAM COALS AND ANTHRACITES.

Data	Steam coals (not including No. 29)	Anthracites
Coal consumed per square foot of grate per hour . .	8·68 lbs.	10·21 lbs.
Refuse per cent. of coal	4·23 p. c.	5·20 p. c.
Water evaporated per hour	24·28 cub. ft.	23·61 cub. ft.
Water evaporated per lb. of coal, from and at 212° F. .	10·95 lbs.	10·05 lbs.
Average pressure of steam, per square inch on the gauge.	52·31 lbs.	55·90 lbs.
Average temperature in the departure flue	335°·5 F.	377°·5 F.
Maximum smoke-shade	2·60	0·00
Average smoke-shade	1·10	0·00
Duration of smoke per hour	1·5 min.	0·0 min.
Number of tests	18	19

The comparison shows that the steam coals evaporated a little more water per hour, and more water per pound of fuel in the ratio of 10·95 lbs. to 10·05 lbs., or nine per cent., than the anthracites. In order to supply the required quantity of steam, the anthracites were burned off more rapidly than the steam coals, and in consequence discharged more heat into the chimney than the steam coals, or the excess of 377°·5 F. of temperature of escaping gases over 335°·5 F. This phenomenon is due to the paucity of flame-borne heat from the combustion of anthracite, in contrast with the greater volumes of bright flame emitted in the combustion of the steam coals. The same total quantity of heat may be generated in the two cases; but more of it is launched by radiation against the plate-surface of the boiler from a largely-flaming fuel than from a non-flaming fuel as anthracite is, since flame is a radiator of heat, and there is a more prompt absorption of the heat that is generated. As the heat is more promptly absorbed, the absorption is effected in a larger proportion also, and consequently the burnt gases pass away at a lower temperature.

The summary results of the three leading tests of Northumberland steam coal and Nixon's Navigation coal, are given in Table XXVIII., on page 142. From this Table

it appears that the Northumberland coal burned off more quickly, and evaporated water more rapidly, than the Nixon coal; but that the Nixon coal was the more efficient, as it evaporated more water per pound of coal than the Northumberland, and, correspondingly, that the temperature at which the burnt gases of the Nixon coal passed away was the lower. The smoke-shades for the Nixon coal are the lighter, and the smoke lasted a shorter time. But the shades were so light, and the duration of smoke was so short, that practically both of the fuels behaved as smokeless fuels. That there was a smoke-making element in the Northumberland coal, was manifested by the result of a special firing. The door was kept closed after firing, so that there was no access for air to enter above the fire. Smoke in consequence came away from the chimney; and it only vanished at the expiration of some minutes after the time of firing.

Table XXVIII.—Summary Results of Tests of Nixon's Navigation Steam Coal and Northumberland Steam Coal.

Data	Nixon's Navigation (large grate)	Northumberland (large grate)	Northumberland (small grate)
Coal consumed per square foot of grate per hour	11·82 lbs.	16·73 lbs.	20·87 lbs.
Refuse per cent. of coal	5·07 per cent.	3·77 per cent.	5·30 per cent.
Water evaporated per hour	66·70 cub. feet	82·10 cub. feet	77·00 cub. feet
Water evaporated per lb. of coal from and at 212° F.	13·25 lbs.	12·22 lbs.	12·62 lbs.
Average pressure of steam per sq. in. on the gauge	atmospheric	atmospheric	atmospheric
Approximate temperature (Fahr.) in the departure flue	500° +	612° +	612° +
Maximum smoke-shade	3	4	4
Average smoke-shade	1·2	2·2	1·8
Duration of smoke per hour	3·6 min.	7·8 min.	14·4 min.
Number of tests	1	1	1

Moreover, when the fire-grate was reduced in area, the evaporative efficiency of the Northumberland coal was augmented to 12·62 lbs. of water per lb. of coal, from and at 212° F., whilst it evaporated 10 cubic feet of water per hour more than the Nixon coal. But it is known that, the greater the rate of gross evaporation of water, the less is the evaporative efficiency; and had the Northumberland coal been limited in the rate of combustion, or in the rate of evaporation, to an equality with that of Nixon's coal, the evaporative efficiencies would also have been equal.

It may, therefore, warrantably be concluded from the evidence of these tests, that, when the coals are treated according to their respective natures, and under the circumstances of the tests, the Northumberland steam coal was substantially of equal evaporative power, efficiency, and smokelessness, with the Nixon's Navigation steam coal.

The evaporative efficiencies of the three artificial fuels were as follows:—

Table XXIX.—Artificial Fuels.—Evaporative Efficiency.

Fuel	Consumption per square foot of grate per hour	Water evaporated per lb. of fuel, from and at 212° F.
Graigola Merthyr	11·26 lbs.	8·41 lbs.
Sanitary	11·46 lbs.	8·88 lbs.
Weardale	17·90 lbs.	8·77 lbs.
Averages	13·54 lbs.	8·69 lbs.

Taking the comparison—on but a very limited basis, it is true—it appears that the artificial fuels made with coal-dust or slack are inferior in evaporative efficiency to either Welsh or North-country steam coals.

D. K. CLARK.

OFFICIAL REPORTS

ON

THE MANCHESTER EXHIBITION.

MANCHESTER SMOKE ABATEMENT EXHIBITION.

REPORT OF THE COMMITTEE.

THE Manchester Smoke Abatement Exhibition was the outcome of that at South Kensington. The Committee of the Manchester Noxious Vapours Abatement Association watched the progress of the Committee which organised the latter with much interest, and the abatement of the nuisance produced by smoke being congenial to their special aim, viz., the suppression of vapours from chemical and allied works, they willingly co-operated with the London Committee, and, further, determined to continue the work by endeavouring to transfer, as far as practicable, the Exhibition bodily to Manchester. The London Committee cordially received this proposal, and, in the work of organising, lent the Manchester Exhibition Committee valuable aid. A Guarantee Fund (the contributors to which will, however, not be called upon) of nearly 2,000*l*. was raised. The Presidents of the London Exhibition (Prince Leopold and the Duke of Westminster) accepted the same office in connection with the Manchester Exhibition, and the experience gained by the Chairman of the London Committee (Mr. Ernest Hart), and the Hon. Sec. (Mr. Wm. R. E. Coles, C. E.), was always available, and proved of the greatest service. The Committee feel that they cannot too warmly thank Mr. Coles for the great interest he took in their work, as indicated not only by his incessant correspondence, but also by his frequent visits to Manchester to advise with them. The Local Committee was formed of members of the Committee of the Noxious Vapours Abatement Association, the local Nobility, Bishops, Clergy, Members of Parliament, Mayors, and other Members and Officials of the Corporations of Manchester, Salford, and surrounding towns, with a number of other representative men and influential citizens. The Mayor of Manchester acted as Chairman of the General Committee, and Mr. Francis Greg (Hon. Sec. of the Noxious Vapours Abatement Association) as Chairman of the Executive. The Corporation of Manchester materially supported the undertaking by granting the use of the Campfield Market, a handsome modern structure, for the Exhibition. They also gave the gas used for illumination free of charge, and accepted about one-half the usual rate in payment for the gas used by the Exhibitors. Special acknowledgment is due to His Worship the Mayor of Manchester for his sympathy with the work and for his frequent advocacy of it.

The Exhibition was opened, on March 17, by the Mayor, who subsequently presided at a luncheon at the Queen's Hotel, where important speeches were delivered.

As a demonstration against the Smoke Nuisance, and as a comprehensive representation of the most approved appliances for the prevention of smoke, the Exhibition was a worthy offspring of that at South Kensington. It may safely be affirmed, too, that it has exercised an important influence in educating public opinion in the district of which Manchester is the centre, the population of the towns represented on the

Committee and intervening districts being in round numbers about 2,000,000. The total number of paying visitors who passed through the turnstiles was 31,563, comprising 9,964 at 1*s.*, 14,608 at 6*d.*, 6,991 at 3*d.*, and 388 by season and day tickets. These figures show *approximately* the class of persons who visited the Exhibition, a large proportion of the admissions at 3*d.* and 6*d.* being of the working class. Every effort was made to utilise the opportunities afforded by the collection of appliances for spreading information respecting them. In a lecture room specially fitted up for the purpose, frequent addresses were delivered, and, in this connection, thanks are due to the following gentlemen for their respective contributions:—

Rev. C. G. K. Gillespie, A.K.C., F.S.A.; on 'The Domestic Application of Heat,' illustrated by numerous experiments.

John Angell, Esq., F.C.S., F.I.C., Science Master, Manchester Grammar School; lecture on 'Burning and Ventilation,' illustrated by experiments.

M. Holroyd Smith, Esq., C.E.; lecture on 'The Mechanical Firing of Steam Boilers,' illustrated by diagrams.

J. West, Esq., Gas Engineer to the Manchester Corporation; lecture on 'Burners, and the various Gas Apparatus in use for Domestic and other purposes.' Practically illustrated.

Thomas Armstrong, Esq., F.R.M.S.; lecture on 'Some Modern Developments of Science.' Illustrated by the oxy-hydrogen lime light.

A. Smithells, Esq., B.Sc., of Owens College; lecture on 'Combustion.' Illustrated by experiments.

All the lectures, except one, were repeated for the benefit of audiences of the working classes. Beside the above, a series of scientific experiments were conducted four times each week, under the superintendence of Professor Core, of Owens College; and a continuous series of cookery lectures, in which the advantages of gas cooking received due prominence, were delivered by ladies in connection with the Edinburgh Domestic Economy Classes. As another means of spreading information on the subject of Smoke Prevention, a paper called *The Exhibition Review* was published by the Secretary, Mr. Fred Scott, to which interesting articles were contributed by Arthur Ransome, M.D., M.A., lecturer on Hygiene at Owens College, on 'The Smoke Nuisance—a Sanitarian's View'; T. C. Horsfall, Esq., on 'The Social Aspect of the Smoke Question'; Rev. C. G. K. Gillespie, A.K.C., F.S.A., on 'Some Aspects of Smoke'; John Angell, Esq., F.C.S., F.I.C., on 'What is Smoke?' A Lady, on 'The Smoke Question'; J. Maule Sutton, M.D., M.R.C.P., Medical Officer of Health for Oldham, on 'The Smoke Nuisance—a Medical Officer of Health's View'; J. Murgatroyd, Esq., F.R.I.B.A., on 'An Architect's View of the Smoke Nuisance'; A. Emrys-Jones, M.D., Hon. Sec. Manchester and Salford Sanitary Association, on 'Smoke and Impure Air'; Leo. H. Grindon, Esq., Author of *The Trees of Old England*, *Manchester Flora*, &c., &c., on 'A Naturalist on Smoke'; Francis Vacher, Esq., F.R.C.S., F.C.S., Medical Officer of Health, Birkenhead, on 'Noxious Vapours'; A Lady, on 'Smoke, and its Effects on Health'; Miss A. Romley Wright, on 'Cooking by Gas'; and Professor Oliver Lodge, on 'Electricity and Gas *versus* Smoke.' The paper also contained reviews of Novelties and Improvements, Correspondence, and paragraphs of interest in connection with the Exhibition. As further means of utilising the Exhibition, a *conversazione* was held in the building, which was attended by nearly 1,000 persons, and visits were arranged for by such bodies as the Nuisance Committee of the Manchester Corporation, the Health Committee of the Salford Corporation, the Manchester and District Union of Gas Engineers, the Bakers of Manchester and Salford (to ee the operation of gas ovens), &c.

An interesting feature in connection with the Exhibition was the interest taken in the work by representatives of the clergy, the Rev. Canon Woodhouse and Rev. C. G. K. Gillespie being most active members of the Executive Committee. Mr. Gillespie, being

curate of the parish in which the Exhibition was held, was enabled to devote special attention to it, and, being a practical scientist, rendered valuable assistance in lecturing and explaining to ladies and others the merits of the several appliances.

Special arrangements were made for a series of tests of articles exhibited, to be conducted by Mr. D. Kinnear Clark, M.Inst.C.E., the Testing Engineer to the Committee, on the lines of the tests which were conducted by him at South Kensington. The reports of these tests form a valuable body of evidence.

The following is a list of the gentlemen who kindly undertook to act as Jurors:—Mr. C. Estcourt, Mr. Herbert Fletcher, Rev. C. G. K. Gillespie, Mr. Francis Greg, Mr. Alderman Harwood, Mr. T. C. Horsfall, Mr. John Littlewood, Mr. T. Newbigging, Mr. John Ramsbottom, Dr. J. Maule Sutton, and Mr. D. Kinnear Clark.

It would be unpardonable to pass from the subject of means adopted for utilising the Exhibition, without acknowledging the powerful and most important aid of the Press of Manchester, and indeed the manufacturing districts generally. Lengthy descriptive reports and articles, warmly commending the work which the Exhibition was meant to illustrate, were freely given, and it is felt that this outcome of the Exhibition alone must have an important bearing upon the welfare of the cause.

As regards the scope of the Exhibition, the promoters, recognising it to be the general one of aiding to prevent pollution of the air by the products of combustion, were enabled, without any sacrifice of principle or straining of the plan, to admit of examples of many subsidiary inventions, some for diminishing the actual production of noxious vapours, some for at least readily removing such vapours when formed, and some for so utilising what are commonly called waste products as to encourage the conservation of what would if dispersed be injurious to the public welfare. Hence, in addition to the strictly technical appliances for use in the combustion of fuel in factories, and the more popularly understood arrangements for domestic purposes, visitors had the opportunity of inspecting and associating with these a large variety of apparatus for regulating and registering their action. Again, the economy of the use of various kinds of fuel received illustration, as also the advantage of greatly diminishing the imperfection of combustion of illuminating materials. The question of the utilisation of gas for yielding heat and light was in many ingenious ways brought nearer to solution. As some injurious products remain after even the most efficient attempts have been made for the healthy warming of living-rooms, invention has been greatly stimulated to devise systems of ventilation with the least loss of heat; and many highly meritorious forms of apparatus were shown, some as parts of the heating apparatus, some of universal applicability dependent in principle upon the action of the ordinary laws of heat.

Many of the constructions gave evidence of genuine scientific consideration by the judicious use of non-conducting materials, the disposal of air passages, the simplicity of detail, and, in some special instances, the artistic excellence of design: evidence that the general question has received much attention from practical men. It is peculiarly gratifying to be able to note that even the brief interval between the London and Manchester Exhibitions was employed by some Exhibitors at the former in the advantageous modification of their appliances, which thus were presented in more efficient forms at the latter.

The classification of the exhibits under their purposes, though sufficient to enable visitors to find them as required, would here be but a repetition of the contents' page of the Catalogue. A more useful review, it is considered, will indicate the principles applied to meet the requirements of each purpose with regard to the general demand for healthfulness and economy. Such an arrangement is here given in outline.

Open Fire Grates: Devices Employed.—Top Feeding, with draught regulators directing warmed air and smoke through the fire; with screens, blowers, or valves, enabling slow or quick combustion; and Bottom Feeding, by means of a shelved incline plane, a

movable base grating; a balanced capsizing basket, or a screen descending as the fuel is burnt downwards.

Stoves and Kitchen Ranges.—Flues inseparable and unaffected by setting; guided so as to distribute the heat in the latter case over the greatest surface if needed, with simple valves giving power of direction; ratcheted base grating, rising when a smaller fire is sufficient; pipes for conducting the hot air apart from all contact with the fire; burners for gas and oil similarly fitted, with cold air inlet from outside the house, and separate outlets for gaseous products and pure warm air. Some excellent sick-room stoves on this principle were shown.

Under these two headings may be briefly noticed the skilful use of non-conducting substances, of which several kinds were shown in the lining of reflectors, and the direction of heat currents with least loss. In some instances air currents were established in remarkably ingenious ways, to ensure almost perfect radiation from reflectors and other surfaces.

Several forms of apparatus, applicable to both domestic and industrial purposes, aimed at the precipitation and removal in solution of noxious acid and other products, by passing the escaping vapours through water.

Ventilators.—Apart from systems included under the previous headings, and some specially devised with extensive radiating surfaces, several mechanical ventilators appeared, from small but effectual modifications of the Archimedean screw principles worked by the chimney draught, to the fan for use in mines by steam power. In addition were to be seen in the Domestic Section some inventions for imparting a rotary or transverse motion to the vapour column by the action of any wind otherwise hostile to its escape.

Gas.—The manufacture of gas for heating and for lighting purposes, both from coal and hydrocarbons, was shown in actual operation and by models of apparatus. In one case the non-luminous gas, produced by the decomposition of steam and air passed through a coal fire, was used to work a singeing machine, a large oven, and an engine, which, in its turn, drove a dynamo-machine, sustaining several electric lights.

For lighting, a large number of exhibits showed that much keen attention had been given to the improvements with regard both to innoxions, *i.e.*, complete combustion of gas, and to the raising of illuminating power. The leading principle, the supply in fitting quantity, and in the proper place and direction, of warmed air to the flame, was shown in practice by many devices, all reducible in effect to three methods, introducing (1) a circular ground of burners yielding sufficient heat to generate from a chamber above a 'regenerative' air-current; (2) a modified Argand burner, having a second bnt shorter chimney outside the usual one, the only inlet for air being the space between these; (3) a pair of 'fish-tail' burners united to a joint supply, so that the flames can coalesce at the upper edge of the 'air of non-combustion,' which thus become much smaller. In addition to these contrivances, many well-known, and some more recent, burners were shown, having the object of (*a*) partly purifying the gas by means of a linen sieve, (*b*) regulating the force of its escape by a permanently adjusted valve.

The leading features of the Industrial Division, in connection with the main object of the Exhibition, consisted of Furnaces of special construction, all practically dependent upon the adaptation of the 'reverberating' principle, by means of internal bridges, platforms, or party walls (in which good opportunity was given for observing the comparative quality of fireclays), aided in most cases by special forms of fire-bars and of Mechanical Stokers, of which nearly all were in action as when at work. For convenience, the latter two may here be grouped together, the object in both cases being to ensure complete combustion within the furnace, while guarding against the fusing together (clinkering) of the waste.

Methods employed with hand-firing included the use of fire-bars, having pyramidal projections, causing the fuel to break up by its own weight as burnt; rocking sideways

by jointed lever action; divided into sets of hand-shaped jointed flaps, capable in each length of being moved upward by one connecting rod and lever, so as to push the fuel forward and sift it. In the Mechanical Stokers the feed was, with two chief exceptions, performed by means of a hopper, usually containing a mill for crushing the fuel to uniform size, from which hopper it was conducted alternately to each side of the furnace, into which it was forced by an iron flap connected with a wheel bearing cams of irregular heights, between which and the flap-lever contact is preserved by a spring powerful enough to jerk the fuel, when released from the highest cam, to the far end of the furnace; by a plunger connected with a crank or an eccentric; by its own weight, through a sliding doorway at the bottom of each side of the hopper; in one instance by a periodical air-blast; and in another by a series of tapered screws revolving in troughs between the gratings of the furnace floor. In addition to these modes of introducing the fuel, among the means for continuing the feed and preventing the formation of clinkers, the most prominent was the regular intermittent movement of the fire-bars, for which the longitudinal direction was in nearly all cases that approved. This was attained by means of a shaft, mounted with cams working in slots at the bar ends; with cams raising and lowering the bars as well as moving them to and fro; with a series of cranks in its length, jointed to frames carrying the bars; itself turned in the lathe on several centres so as to become a set of eccentrics to which the ends of the bars are strapped.

In all the departments, and especially in the Industrial, and the less necessarily ornamental portion of the Domestic Division, it could be seen that simplicity, small number, and accessibleness of working parts, and the easy renewal of wearing parts, had not been omitted from the many considerations of invention and manufacture: and this Exhibition may fairly be credited with having, to some definite extent, aided a large section of the public, and those who cater for them, towards an extended knowledge and satisfaction of the sanitary needs to which its origin was due.

The list of Awards recommended by the Jurors and passed by the Committee, is contained in the Report of the Jurors. It is also given in the Report of the London Committee, page 9.

REPORT OF THE JURORS

(MANCHESTER EXHIBITION).

THE Jurors have the satisfaction of announcing that, in the Exhibition at Manchester, following closely upon the South Kensington Exhibition, marks of improvement were observable. They are pleased in being able to recommend for awards the works of several local exhibitors; and they are of opinion that the articles which have been submitted for testing, though comparatively restricted in number, are fairly representative of the Exhibition in its entirety.

From the Reports of the Testing Engineer, it appears that eleven tests were made of open grates and close stoves burning solid fuel, six tests of gas-heating grates and stoves, five tests of kitcheners and cooking-stoves, two tests of Dowson's gas-producer and the application of the gas, and seven tests of steam-boiler appliances, comprising three mechanical stokers; making together 31 tests, all of them distinctive of the Manchester Exhibition.

It is not necessary that the Jurors should enter into an analysis of the merits of the various articles which were tested: a duty which has already been performed by the Testing Engineer. They confine themselves to a brief notification of such of the articles tested as they recommend for awards to the Committee, as follows:—

LIST OF AWARDS.

To T. E. PARKER, London, for his Smoke-Preventing Grate, the 'Vencedor,' being an improvement upon the grate exhibited by him in London, Silver Medal.

To JAFFREY & Co., Manchester, for their Smoke-Consuming Grate, being an improvement on Ingram's Kaio-Kapnos Grate exhibited at South Kensington, Silver Medal.

To J. WADSWORTH, Manchester, for his Close Ventilating-Stoves, burning coke, and burning gas, Silver Medal.

To THE FALKIRK IRON COMPANY, London, for improved Coke-and-Gas Fire, and Asbestos-and-Gas Fire, modifications of Dr. Siemens' principle, Silver Medal.

To W. THORNBURN, Boroughbridge, for his Hot-Air Petroleum Stove, Honourable Mention.

To E. H. SHORLAND, Manchester, for the Manchester Close Stove (G. L. Shorland's patent), Bronze Medal.

To JAMES MOORE, Bromley-by-Bow, for his system of Boiler-Seating with Perforated Bridges and Steam Jets, for the prevention of smoke and for economy of fuel, Bronze Medal.

To J. HAMPTON, Loughborough, for his Fireproof Smoke-Consuming Bridge, Bronze Medal.

To B. GOODFELLOW, Hyde, for Johnson's Smoke-and-Fume Washer, Honourable Mention.

To HYDES & WIGFULL, Sheffield, for the 'Tortoise' Laundry-Stove, Bronze Medal.

To ELLIOTT, ALSTON, & OLNEY, Manchester, for Senking's Cooking-Stove, Silver Medal.

To R. W. CROSTHWAITE, London, for Close-fire Range, having Gregory's Furnace, Silver Medal.

To WADDELL & MAIN, Glasgow, for improved Gas Cooking-Stove, Silver Medal.

To CHARLES WILSON, Leeds, for improved Gas Cooking-Stove, Silver Medal.

To R. W. CROSTHWAITE, London, for Gregory's Smoke-burning Furnace, applied to an upright boiler, Silver Medal.

To E. BENNIS, Bolton, for his Mechanical Stoker, Silver Medal.

To THOMAS HENDERSON, Liverpool, for his Furnace-front and Fire-door, Bronze Medal.

To MICHEL PERRET, Paris, for his Multiple-Staged Furnace, Silver Medal.

The Jurors are of opinion that, as the test of the gas cooking-stove of John Wright & Co., whilst it yielded generally good results, was made under the special condition of a very contracted flue-way, with deficiency of ventilation,—it was not eligible for competition for an award.

The Jurors recognise and highly appreciate the merits of the Non-Conducting Composition exhibited by Joseph Kershaw & Co., and of the Gas Regulator exhibited by James Stott & Co.; and they were prepared to recommend awards of a Silver Medal to each of these exhibitors. But it had been ruled by the Jurors for the South Kensington Exhibition that articles like those now in question, which were more properly accessories than articles directly conducive to the abatement of smoke, were not eligible for awards. The Jurors, therefore, limit themselves to an expression of their sense of the very considerable merits of Kershaw's Non-Conducting Composition and Stott's Gas Regulator.

REPORTS OF THE TESTING ENGINEER
(MANCHESTER EXHIBITION).

I. REPORT ON TESTS OF OPEN GRATES AND CLOSE STOVES.

FOR the purpose of testing open grates and stoves, two rooms in a brick-built house facing the Exhibition were prepared. The rooms were designated No. 2 and No. 3 respectively, and were nearly rectangular. No. 2 room averaged 13 feet wide, 14 feet long, and 9 feet 6 inches high. The door was in one side, facing the fire-place on the other side, and the window, measuring 4¼ feet by 6¼ feet, was at one end facing the street, with a southern aspect. No. 3 room averaged 13 feet 4 inches wide, and was 14½ feet long, and 9½ feet high. There were two windows, 4 feet 4 inches wide, and 6¾ feet high, having respectively a southern and an easterly aspect, one facing the fire-place, the other the doorway. The chimneys were 14 inches square.

The rooms were prepared, and the tests were conducted, similarly to the testing-rooms and the tests at the Smoke Abatement Exhibition, South Kensington. Thermometers were suspended at three walls in each room—the wall facing the fire-place, the wall in which the fire-place was constructed, and one of the side walls. They were laid at three different levels:—at 6 inches, 5 feet, and 8½ feet above the floor, numbering altogether nine thermometers at the walls.

For the purpose of measuring relatively the radiating power of each grate or stove, three pairs of thermometers were suspended at different levels, on an upright post, placed at a distance of 6 feet from the front of the grate or stove. One of each pair was suspended directly facing the fire, exposed to the direct radiant heat; and the other was suspended back to back with the first, on the other side of the post, exposed only to the atmosphere of the room. The difference of the indications of each pair of thermometers was taken as a measure of the radiating power of the fire. The three several pairs were placed at the same levels as the thermometers at the walls. The temperature of the ascending current of smoke in the chimney was measured, at intervals, by a thermometer which was introduced through an opening into the flue, at a height of 8 feet above the floor; and the upward velocity of the current was at the same time measured by means of an anemometer passed through the same opening.

The classification of grates and stoves burning solid fuels, that was adopted at South Kensington, is here followed in indicating the number of the class to which each grate or stove is referred.

OPEN GRATES.

No. 1. A. C. ENGERT & Co.—The 'Solo' Grate: of barrel form (Class 1). This grate was exhibited and tested at the South Kensington Exhibition, and it has already been described at page 50. It was differently managed when tested at Manchester, inasmuch

as the grate was filled up with coal at the commencement of the test, and the coal was lit at the top, and allowed to burn downwards, chiefly at the front, without disturbance. The mass of coal was moved forward as required, by means of the internal adjustable barrel-form plate. The 'Solo' Grate, it is stated, is capable when once filled of burning for from 20 to 26 hours without any additional supply of fuel.

No. 2. THE GAS METER COMPANY.—W. Sugg & Co.'s Stove, burning coke; portable (Class 1). The fire-bars were nearly semi-circular, forming the front and the bottom together. The draught passed upwards and through the back to the flue.

No. 3. E. H. SHORLAND.—The 'Improved Manchester' Grate (G. L. Shorland's patent) (Class 5). The 'Manchester' Grate, tested at South Kensington, has been described at page 50. The improvement consists in the combination of a downward draught through the grate with the upward draught.

No. 4. T. E. PARKER.—The 'Vencedor' Downward-draught Grate (Class 5). As tested at South Kensington, this grate has been described at page 55. Increased facility is provided for the entrance of heated air at the lower back corner of the grate.

No. 5. CLARK, BUNNETT & Co.—Ingram's 'Kaio-Kapnos' Grate (Class 5). This grate has already been described, page 54.

No. 6. JAFFREY & Co.—This grate (Class 2) is a modification of Ingram's 'Kaio-Kapnos' Grate. The back and sides are blocks of fireclay. The floor also is of fireclay, and is solid. The draught passes direct from the fire between a number of upright slabs of fireclay, resting on the floor and reared up against the back; thence downwards to the ashpit below the floor-slab, whence it passes through a perforated block of fireclay, into a flue which rises behind the back of the grate and is enclosed with iron. Air is admitted by a slit through the floor lump into the ashpit, to promote combustion there. The draught may be partially directed upwards through the register. Stray gases rising upwards, when the register is closed, pass off through two small openings at the upper part, into a flue at each side of the grate, downwards into the ashpit, whence they pass through to the back flue. (Plates 68, 69.)

CLOSE STOVES.

No. 7. W. BARTON.—The 'Premier' Stove (Class 6): already described, page 58. The stove tested in Manchester was 10 inches in diameter inside.

No. 8. HYDES & WIGFULL.—The 'Tortoise' Laundry-Stove (Class 6). The 'Tortoise' Stove, for heating rooms, has been described, page 56. Adapted for the laundry, the stove is eight-sided, 8 inches wide inside, and standing 32 inches high. It is made with three tiers of shelves or brackets, on all sides, capable of holding 24 irons at once for being heated. (Plate 67.)

No. 9. A. C. ENGERT & Co.—Baker's oven (Class 6): designed as an auxiliary to ordinary bakers' ovens. It consists of an iron box which is pushed into the furnace-mouth, holding the coals to be consumed. It is entirely close except at the inner end from which the products of combustion pass into the oven. The air for combustion is admitted at the front, through holes in the lower side.

No. 10. E. H. SHORLAND.—Warm-Air Ventilating-Stove, for large buildings: (G. L. Shorland's patent) (Class 6). A cubical stove, having a casing of cast-iron, made with gills externally, ⅜ inch deep. The fire-place is square, and is enclosed at the sides and the back by air-warming chambers. A few steel turnings are suspended in the fire-place, which, becoming red hot, are expected to be useful in burning smoke. Fresh air is led

into a shallow reception-chamber at the base of the stove. Thence it passes upwards through the air-warming chambers, which are made with partitions by which the air is caused to ascend in a zigzag course. The air passes from the upper parts of these chambers into pipes, which rise from each side, and from the back, meet at the middle of the stove over the fire, and deliver the warmed air into a shallow receptacle on the top of the stove, whence it passes through numerous openings into the room. These openings are formed by short pieces of tube which are fixed to the bottom of a shallow tray containing water, and rise through the water. By this means, moisture is distributed with the air into the building. The products of combustion are led away through a descending flue at the back, under the floor. (Plate 67.)

No. 11. J. WADSWORTH.—The 'Pioneer,' a Warming, Ventilating, and Cooking Apparatus: a close stove (Class 6), burning coke. The stove is cubical, of charcoal iron sheets, 36 inches high, 20 inches wide, 16 inches deep. The fire-place, which is at the bottom, is 7 inches by 6 inches, and 7 inches deep, grated in front, with a hob-plate at the top, having a 6-inch opening, with a hinged cover. The fire-place, indented into the casing, and flush with it, is enclosed and over-arched by plating, so as to leave a space above the hob for cooking. It is enclosed in front by a lean-to, paned with talc, to let the fire be seen. A sliding damper is fitted at each side of the fire-place, under the hob, to regulate the draught which passes off from the fire-place into the interior of the casing, where air is heated. The air to be heated comes from the external atmosphere, through a pipe, and is delivered into a shallow chamber at the base, whence it passes upwards through five flat conduits 30 inches high, of which three are 5 inches by 1 inch, and two are 3 inches by 1 inch. Air from the room, near the floor, is also admitted at the base of the stove, to pass up through four conduits, 5 inches by 1 inch in section. Through the nine conduits here noticed, the air passes upwards within the casing, enveloped by the hot gases from the fire. The air becomes heated as it ascends, and is distribnted warm into the room through numerous apertures in a shallow chamber at the top, in which the heated currents of air are collected. Foul air is collected from the upper part of the room, through a ventilator, and is conducted by a pipe in the chimney, where it becomes warm as it descends, and is delivered below and above the fire, to supply air for combustion. The products of combustion pass away through the back of the stove, at the level of half the height of the stove, into the flue to the chimney. Stray gases and fumes from the hob-plate are conducted through the crown of the arch enclosure into the flue-pipe. Cooking can be effectually conducted on the hob; and, by enclosing the space over the hob, small joints can be roasted.

GAS HEATING-GRATES AND STOVES.—COMBINATION FIRES.

No. 12. THE GAS METER COMPANY.—W. Sugg and Co.'s Gas-and-Coke Stove: An ordinary portable grate, in which coke is heaped, and is ignited by means of a line of jets of gas at the front, between the bars of the bottom grid.

No. 13. THE FALKIRK IRON COMPANY.—Register Grate, having a gas-and-asbestos fire, on a modification of Dr. Siemens' principle. The fire-place is 18 inches wide at the front, and 13 inches at the back, and is $4\frac{1}{2}$ inches deep from front to back at the grid, and $5\frac{3}{4}$ inches at the upper bar. The upper bar is 5 inches above the grid. The fire-bars are made of great depth—$3\frac{1}{4}$ inches—in order to heat the air for combustion as it passes up between them. A row of ten atmospheric burners is placed at the front, beneath the fire-bars, each burner being carried on a separate branch or nozzle-pipe, which passes up, in each alternate interspace, between the bars, and delivers the jet of gas at the surface of the grid. An additional jet is placed in the middle near the back of the grate. The back

is of firebrick, 2½ inches thick, and is perforated for the passage of air from behind the back into the body of the fire, to aid in completing combustion.

No. 14. The Falkirk Iron Company.—Register Grate, having a gas-and-coke fire, on a modification of Dr. Siemens' principle. The fire-place is 18 inches wide at the front, and 11¼ inches at the back; 7½ inches deep from front to back at the grid, and 8 inches at the upper bar. This bar is 5 inches above the bottom. The back and sides are of iron. The fire-bars are 3½ inches deep, and are undercut at the front, to make room for the gas-pipe, which lies within half an inch of the surface of the grid. From this pipe ten atmospheric jets are delivered between the bars, directed upwards, at an angle backwards, into the body of the fire, made up of coke. On this system, the air and the gas are heated previously to their entering into combustion. (Plate 67.)

No. 15. W. T. Braham.—Warming and Ventilating Gas Stove: a cubical case 16 inches high, 12 inches wide, and 8½ inches deep; with a cover forming a shallow chamber on the top, for the distribution of warmed air. A line of atmospheric gas jets is placed at the bottom, the flame and gases of which rise into a box containing asbestos, from which the burnt gases pass off at the back, at the upper part, into a flue. The bottom of the box of asbestos is sloped upwards at the front, and is grilled, in order that the gas-flames may pass amongst the asbestos, at the same time that heat is radiated through a mica door in the front of the case into the room. The back of the asbestos-box is a hollow chamber, 2½ inches wide for the whole depth, into which fresh air is admitted; and from which the air, after having been warmed, is delivered, through two openings at the top, into the distributing-chamber already mentioned.

No. 16. J. Wadsworth.—'Pioneer' Gas-Stove. The case and the air conduits are designed similarly to the coke-stove No. 11. The heat is produced by burning atmospheric gas in a ring of jets enclosed in a small fire-chamber, placed as in the coke-stove, with a small quantity of asbestos to make a lively appearance. The case measures 30 inches high, 17 inches wide, and 15 inches deep; and contains eight air-conduits, in passing through which, external air, and air from the room, are warmed. The foul air at the upper part of the room is not extracted as with the coke-stove, but the products of combustion are all discharged into a flue.

PETROLEUM HEATING STOVE.

No. 17. W. Thornburn.—Petroleum Heating-Stove, No. 2. The gaseous products from two petroleum lamps, fitted with 1-inch duplex burners, ascend into an upright cylindrical heater immediately above the lamps, in which fresh air from the room is warmed. For this purpose, the heater is double, consisting of two concentric cylinders made of block tin, enclosing an annular space; the inner cylinder being traversed by twenty ½-inch copper tubes in four tiers, through which the air in the annular space is circulated. The tubes are slightly inclined, so as to determine a regular circulation of air. The inner cylinder is 6 inches in diameter and 12 inches high, the outer cylinder is 7 inches by 14 inches, enclosing an annular space about ½ inch in width, and a shallow space 1 inch deep between the bottoms of the two cylinders. The glasses of the two lamps enter each into a short tin tube a little larger in diameter than the glasses, fixed to the bottom of the heater. The products of combustion pass into the inner cylinder, together with a proportion of free air passed in around the glasses, in order to insure completeness of combustion and absence of smell. The hot gases part with their heat to the inner cylinder and to the transverse tubes, by which the air in the annular space and the tubes is warmed, and they pass off through a perforated plate at the top into the room. The warmed air passes off at the upper part of the annular space into the room, and is replaced by air from the room, which enters the shallow interspace at the bottom, through three ½-inch holes, and passes to the annular space. (Plate 69.)

TABLE XXX.—RESULTS OF TESTS OF OPEN GRATES

No. of test	No. of testing room	Date	Name of exhibitor	Description	Time under trial
1	2	3	4	5	6
		1882	OPEN GRATES.		h. m.
1	3	April 24	A. C. Engert & Co. . .	'Solo' Grate, barrel form (Class 1)	6 0
2	2	„ 25	The Gas Meter Company.	W. Sugg & Co.'s Stove, burning coke (Class 1) . .	6 0
3	2	„ 27	E. H. Shorland . .	'Improved Manchester' Grate, (G. L. Shorland's patent) (Class 5)	4 30
4	2	May 3	T. E. Parker . . .	'Vencedor' Grate (Class 5)	5 0
5	3	„ 4	Clark, Bunnett & Co. .	Ingram's 'Kaio-Kapnos' Grate (Class 2) . . .	6 0
6	3	„ 6	Jaffrey & Co. . . .	Firebrick lining and floor (Class 2)	6 0
			CLOSE STOVES.		
7	3	April 27	W. Barton . . .	'Premier' Stove (Class 6)	4 30
8	3	„ 29	Hydes & Wigfull . .	'Tortoise' Laundry-Stove (Class 6)	6 0
9	3	May 3	A. C. Engert & Co. .	Baker's Oven (Class 6)	2 30
10	Exhib.	„ 6	E. H. Shorland . .	Warm-Air Stove (G. L. Shorland's patent) (Class 6) .	5 0
11	3	„ 9	J. Wadsworth . .	'Pioneer' Stove (Class 6)	5 5

TABLE XXXI.—RESULTS OF TESTS OF GAS

No. of test	No. of testing room	Date	Name of exhibitor	Description	Time under trial
1	2	3	4	5	6
		1882			h. m.
12	2	April 28	The Gas Meter Company	W. Sugg & Co.'s Gas-and-Coke Stove . . .	6 0
13	Upper Thames St.	July 5	The Falkirk Iron Company . .	Register Grate, gas and asbestos	5 0
14	Do.	„ 6	Do. do. .	Register Grate, gas and coke	5 0
15	2	May 6	W. T. Braham . .	Ventilating Gas Stove	5 45
16	2	„ 9	J. Wadsworth . .	'Pioneer' Gas Stove	4 0
				PETROLEUM STOVE.	
17	3	April 28	W. Thornburn . .	Petroleum Heating-Stove, No. 2	6 0

AND CLOSE STOVES FOR HEATING, 1882. (MANCHESTER.)

No. of test	Fuel Consumed				Ash	Temperatures						Chimney				Smoke-Shade	
	Wood	Coal or coke: Total: Description	Coal or coke: Total: Weight	Coal or coke: Per hour		External average	At walls 5 feet high: At commencement	At walls 5 feet high: Total average	At walls 5 feet high: Average, last hour	Difference due to radiation 5 ft. high, 6 ft. from fire: Total average	Difference due to radiation: Average, last hour	Velocity of draught: Total average	Velocity of draught: Average, last hour	Temperature: Total average	Temperature: Average, last hour	Total average	Average, last hour
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	oz.		lb. oz.	lb. oz.	lb. oz.	Fahr.	Fahr.	Fahr.	Fahr.	Fahr.	Fahr.	ft. per min.	ft. per min.	Fahr.	Fahr.	No.	No.
1	24	Silkstone .	26 0	4 5½	—	52·0	54·1	66·1	72·6	16·3	22·0	123·7	132·4	143·9	160·0	1·23	0·0
2	8	{ Silkstone coke .	6 0 21 0	4 8	1 2	50·1	53·2	62·7	67·3	13·0	16·0	102·5	105·8	110·4	131·7	0·77	0·0
3	10	Silkstone .	27 8	4 9¼	1	51·1	54·0	72·7	86·9	14·3	22·3	137·6	133·3	224·6	250·0	1·46	0·0
4	24	Do. .	21 8	4 4¾	0 8	59·7	59·0	81·7	90·5	13·7	12·8	—	—	330·0	—	0·47	0·0
5	16	Do. .	38 8	6 6¾	—	60·1	56·7	71·1	80·2	17·0	19·8	127·0	128·1	300·0	—	1·23	1·0
6	16	Do. .	23 6	3 14¼	0 4	60·8	58·7	71·8	78·9	13·5	15·7	141·1	—	240·0	240·0	1·35	0·67
7	15	Coke .	25 8	5 10½	3 8	52·1	52·5	80·4	58·3	7·8	7·0	150·0	120·0	283·9	256·7	0·50	0·0
8	24	Do. .	29 12	4 15¼	1 4	44·1	51·7	75·0	81·1	7·2	7·5	—	—	—	—	0·46	0·0
9	8	Silkstone .	7 0	2 13	—	—	—	—	—	—	—	—	—	—	—	1·60	0·0
10	24	Do. .	25 4	5 1	0 10	—	—	—	—	—	—	115·4	—	300·0	—	1·05	0·0
11	8	{ Silkstone coke .	1 0 14 2	2 15½	0 12	54·7	53·5	67·4	73·0	1	5·4	—	—	—	—	0·80	0·0

HEATING-GRATES AND STOVES, 1882. (MANCHESTER.)

No of test	Fuel Consumed				Quantity of gas consumed	Time burning gas	Temperature					
	Description	Weight	Ash	Per cent.			External	At walls 5 feet high: At commencement	At walls 5 feet high: Total average	At walls 5 feet high: Average, last hour	Difference due to radiation, 6 feet from fire, 5 feet high: Total average	Difference due to radiation: Average, last hour
	7	8	9	10	11	12	13	14	15	16	17	18
		lb. oz.	lb. oz.	per ct.	cub. ft.	h. m.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
12	Coke . .	6 8	0 12	11½	25	0 30	54·5	52·3	60·6	74·4	7·0	7·0
13	Asbestos .	—	—	—	219	5 0	66·3	65·5	71·8	74·5	8·5	10·0
14	Coke . .	15 5	1 3	7¾	30	0 50	64·2	62·5	74·9	80·0	15·5	17·0
15	Asbestos .	—	—	—	61	5 45	58·0	60	68·7	72·1	0·5	1·3
16	Do. .	—	—	—	27·5	4 0	55·0	58·0	64·6	68·0	0·6	0·5
17	—	—	—	—	Petroleum lb. oz. 1 8	Petroleum h. m. 6 0	54·1	52·7	62·0	63·6	—	—

RESULTS OF TESTS OF OPEN GRATES AND CLOSE STOVES.

The results of the tests of grates and stoves are given in Tables XXX. and XXXI. (pp. 154, 155), in which are comprised the results for eleven grates and stoves burning solid fuels, five grates and stoves burning gas, or gas and coke, and one petroleum stove; making together seventeen tests. The tests were conducted in the rooms already described, with the exception of No. 10, which was conducted in the Exhibition building where the stove was exhibited; and Nos. 15 and 16, which were conducted in a room at 67 Upper Thames Street, London, measuring 15 feet by 14 feet, and 8 feet 9 inches high, where the grate was placed in one corner.

The supply of gas for the tests made in Manchester was obtained from the Gas Committee of the Manchester Corporation.

DEDUCTIONS.

The leading results of the tests are abstracted in the following Table (XXXII.), for direct comparison. The average rise of temperature per pound of fuel per hour, with the smoke-shade, are given for Nos. 1 to 11, in which solid fuel was consumed. For the gas-heating and petroleum grates and stoves, Nos. 12 to 17, the quantities consumed and the elevation of temperature are given; also, in two instances, the elevation of temperature per cubic foot of gas.

In T. E. Parker's 'Vencedor' Grate (No. 4) the good effects of the increased facility provided for the entrance of warmed air at the lower back corner of the grate, is made apparent in the very light smoke-shade by which the performance at Manchester was effected, relatively to the smoke-shade at South Kensington.

No. 5, by Clark, Bunnett & Co., and No. 6, by Jaffrey & Co., afford an instructive contrast; showing that No. 6 did one-half more heating duty per pound of coal consumed. The grates act on the same principle, having a backward and a down ward draught, over and through firebrick pieces. But there is a difference in detail: in No. 5, the current passes undivided over the back and under the bottom; whilst in No. 6, the current is divided into numerous streams, passing between the sections or ribs of the back, and also through the grid under the bottom, leading to the flue.

The close stoves burning solid fuel manifest a higher degree of efficiency than the open grates:—conformably to the experience at South Kensington.

No. 15, W. T. Braham's Gas Stove, and No. 16, J. Wadsworth's Gas Stove, show, by contrast, the advantage, in the second instance, of fully developing the area of surface for heating air, where 17 per cent. more efficiency is obtained than in the first instance.

The Petroleum Stove of W. Thornburn shows a very high degree of efficiency—an average rise of 37° of temperature for 1 lb. of petroleum consumed per hour. But a large proportion of this rise results from the detention of the products of combustion in the room, and their intermixture with the atmosphere of the room. It is maintained that the discharge of such gaseous products of petroleum into a room is harmless; but it cannot be disputed that a purer atmosphere would be maintained if the gaseous products of combustion were ejected from the room.

TABLE XXXII.—FUEL AND RISE OF TEMPERATURE IN GRATES AND STOVES. (MANCHESTER.)

No. of test	Exhibitor	Fuel consumed per hour	Average rise of temperature		Average smoke-shade
			Total	Per lb. of fuel per hour	
	OPEN GRATES.	lbs.	Fahr.	Fahr.	
1	A. C. Engert & Co.	coal 4·32	12°	2·78°	1·23
2	The Gas Meter Co. (Sugg's grate)	coal, coke 4·50	9·5	2·11	0·77
3	E. H. Shorland (G. L. Shorland's patent)	coal 4·58	18·7	4·09	1·46
4	T. E. Parker	coal 4·30	22·7	5·28	0·47
5	Clark, Bunnett & Co.	coal 6·42	14·4	2·24	1·23
6	Jaffrey & Co.	coal 3·90	13·1	3·36	1·35
	CLOSE STOVES.				
7	W. Barton	coke 5·65	27·9	4·93	0·50
8	Hydes & Wigfull	coke 4·95	23·3	4·71	0·46
9	A. C. Engert & Co.	coal 2·81	—	—	1·60
10	E. H. Shorland (G. L. Shorland's patent)	coal 5·06	—	—	1·05
11	J. Wadsworth	coal, coke 2·97	13·9	4·68	0·80
	GAS HEATING-GRATES AND STOVES.				
12	The Gas Meter Co. (Sugg's grate)	coke 1·08 lb., gas 4·20 cub. ft.	13·3	—	—
13	The Falkirk Iron Co.	gas 43·80 cub. ft.	6·3	—	—
14	Do. do.	coke 3·06 lb., gas 6·00 cub. ft.	12·4	—	—
15	W. T. Braham	gas 10·60 cub. ft.	8·7	0·82 per c. ft.	—
16	J. Wadsworth	gas 6·90 cub. ft.	6·6	0·96 do.	—
	PETROLEUM STOVE.				
17	W. Thornburn	Petrol. 0·25 lb.	9·3	37·2 per lb.	—

D. K. CLARK.

NOTE.—THE MANCHESTER STOVE (G. L. Shorland's Patent), tested at Manchester (p. 151).

THIS stove was specially tested for combustion of fuel without smoke, and chimney draught and temperature. But observations were taken, at the same time, of the temperature of the air which was heated in the stove, and the velocity of its discharge.

The stove was cold, and the fire was lighted, at the commencement of the trial, which lasted five hours, when the external temperature was 50° Fahr. The temperature of the heated air, as discharged, rose from 63° at the commencement, to 120° an hour later, 230° two hours later, and 280° three hours later. During the succeeding two hours of the special trial, the temperature varied from 380° to 440°, and it could have been so maintained continuously, if it had been desired, for any length of time, at the same rate of combustion of fuel as during the special trial.

It may be mentioned that after the special test was concluded, and the fire had been drawn, heated air continued to flow from the stove, and was as high as 120° in temperature four hours after the test was concluded.

The velocity of discharge of the heated air averaged 120 feet per minute during the trial, making a volume of 13,000 cubic feet of heated air delivered per hour.

The stove, it may be mentioned, is lined with fireclay, and is adapted for burning any kind of fuel.

D. K. C.

II. REPORT ON TESTS OF KITCHENERS AND COOKING-STOVES.

FOUR kitcheners and cooking-stoves were tested, of which two were coal-burning and two were gas-burning, as follows:—

1. ELLIOTT, ALSTON & OLNEY: Senking's Cooking-Stove No. 1 B B.—It is self-contained, 38 inches wide, 29 inches high, and 26 inches deep. The upper part, under the hot plate, is occupied by the fire-place at one end—8 inches wide, 5 inches high, and 13 inches deep; a copper side-boiler, holding 2½ gallons, at the other end; and a roasting-oven, 14 inches by 9 inches high, and 24 inches deep, in the middle. The lower part contains a baking-oven. The stove was tested, May 10, 1882, by the roasting of a sirloin joint weighing 11 lbs. 3 oz. It weighed when roasted 8 lbs. 4 oz.; the dripping weighed 1 lb. 11 oz.; together, 9 lbs. 15 oz.; loss of weight, 1 lb. 4 oz., being 11 per cent. of the gross weight. The joint was fairly well done. The temperature attained in the oven varied from 265° F., at the commencement, to 400° when the joint was withdrawn; the period of cooking being 1 hour 25 minutes. The oven was heated up again for pastry, to upwards of 400°, and maintained at that temperature for 12 minutes. The quantity of coal consumed was 8¼ lbs. (Plate 70.)

2. R. W. CROSTHWAITE.—Close-fire Range, having C. B. Gregory's Smoke-burning Furnace, set in brick flues at the ends. It is 5½ feet wide, 30 inches high, and 19 inches deep. The fire-place is in the centre, with the baking-oven to the left hand, and the roasting-oven to the right hand. For the baking-oven, the draught is conducted from the fire-place down the side of the oven, under the bottom, up the outside, over the top, and thence to the flue. For the roaster, the draught is over the top, down the outside, under the bottom, and up the back, to the flue. The fire-place is 11 inches wide, having an inclined grate landed on a horizontal grate, fed from a hopper at the front, whence the coal falls as it is consumed. The sides, the back, and the roof are of fire-tiles. Air from the front is admitted at each side, outside the fire-tiles, whence it passes over the top, and to the back. It is delivered in two streams, at the throat of the furnace, to meet the current of combustible gases rising from the furnace, in front and at the back; and so combustion is completed.

This range was tested, July 8, 1882, at 153 Queen Victoria Street, London: roasting a sirloin joint weighing 12 lbs. 13 oz. when it was laid in. The joint weighed when roasted 9 lbs. 5½ oz.; the dripping weighed 2 lbs. 2½ oz.; together, 11½ lbs. The loss of weight was 1 lb. 5 oz., or 11½ per cent. The joint was roasted in 2 hours 10 minutes, and it was very well done. Twenty-four minutes more were allowed for heating up the oven and maintaining the temperature at 400° F. for pastry. The total quantity of coal consumed was 10 lbs. 13 oz. If the joint had been drawn ten or twelve minutes earlier than it was drawn, it would have been sufficiently well done, and the whole of the work of the test could probably have been performed with a consumption of 10 lbs. of coal.

3. CHARLES WILSON.—Gas Cooking-Stove, of type 4, already defined (p. 109) as being heated by atmospheric jets inside at the bottom. In this stove, compared with that of the same exhibitor which was tested at South Kensington, the speciality is that it is encased at the sides and the back by a double air-jacket—each air-space being

⅜-inch wide—instead of only one air-jacket, as before, and that the number of jets of gas has been reduced from 24 to 15, of which 8 jets are on one side, and 7 jets on the other side. The oven is 15½ inches wide, 27 inches high, and 16 inches deep. It was tested April 28, 1882, roasting a sirloin joint weighing 12½ lbs. when put into the oven. The joint weighed 10¼ lbs. when withdrawn; the dripping weighed 9 oz.; making together 10 lbs. 13 oz.; showing a loss of 1 lb. 11 oz., or 13½ per cent. The stove was heated to 250° F. in five minutes; the joint was in the oven for 2 hours, when the temperature was 380°. The temperature was raised to 390° at the end of twelve minutes, the time allowed for pastry. The total time during which the gas was burning was 2 hours 12 minutes, during which time 27½ cubic feet of gas were consumed. Of this, 25 cubic feet were consumed in heating up and roasting. The joint was very well done.

4. WADDELL & MAIN.—The 'Universal Domestic' Gas Cooking-Stove, No. 2: of the same class of gas-stove as that which was tested at South Kensington (see p. 109), 32 inches high, 16½ inches wide, and 15½ inches deep externally; and 22 inches high, 13½ inches wide, and 14 inches deep internally. It is lined with fire-tiles, and is heated with 18 white-gas burners at the sides and the front and back. This stove was tested, May 8, 1882, in roasting a sirloin joint 12 lbs. 1 oz. in weight. The joint weighed when withdrawn 9 lbs. 6 oz., and the dripping 1 lb. 9 oz.; making together 10 lbs. 15 oz., showing a loss of 1 lb. 2 oz., or 9·30 per cent. The time required to heat the oven to 280° F. was 12 minutes; to cook the joint, 1 hour 44 minutes; to heat up for and cook puff pastry at upwards of 400°, 18 minutes; for the whole operation, 2 hours 14 minutes. The quantity of gas consumed was 29 cubic feet; and the joint was very well done.

5. JOHN WRIGHT & CO.—Gas Cooking-Stove, of the same class as the gas stove exhibited by the firm at South Kensington (see page 110). The oven is 14 inches wide, 14 inches deep, and 28 inches high; encased in slag wool. A sirloin joint weighing 11 lbs. 14 oz. was roasted in 2 hours 5 minutes; and it weighed when taken out 9 lbs. The dripping weighed 1½ lbs., and the loss in weight was 1 lb. 3 oz., or 10 per cent. The temperature when the joint was taken out was 400° F. The oven remained under gas for 12 minutes longer to allow for pastry. The quantity of gas consumed was 22·68 cubic feet; and the joint was very well done. The outlet flue-pipe, 2 inches in diameter, had been reduced at the exit to a small opening ¾-inch in diameter. The ventilation was thus impeded, and a close smell was caused in the testing room.

DEDUCTIONS.

These results of tests for cooking sirloin joints are excellent. The Close-fire Range of R. W. Crosthwaite, with Gregory's Furnace, is particularly good, although it has but very recently been introduced. Its operation will no doubt be improved as experience is gained; and it is likely to take the lead for economy of fuel.

The efficiency of Charles Wilson's Gas Cooking-Stove appears to have been augmented in consequence of the employment of a double air-casing. For, whilst with the double casing, tested at Manchester, only 27½ cubic feet of gas were consumed, with the single casing, as tested at South Kensington (p. 110), 45½ cubic feet of gas were consumed. Waddell & Main, in testing an oven at Manchester of the same description as that which was tested at South Kensington, consumed much less gas than before: 29 cubic feet against 45 cubic feet. The saving of gas is apparently accounted for by the difference of time: 2 hours 14 minutes against 3 hours 3 minutes at South Kensington (see p. 110); together with improved ventilation and escapement.

D. K. CLARK.

III. REPORT ON TESTS OF DOWSON'S GAS-PRODUCERS.

The Dowson Economic Gas Company's Gas-Producer was tested at Manchester for the production of gas. For the sake of convenience, the report on the results of the test, and the report on the Gas Singeing Machine exhibited by Joseph Robinson & Co., have been grouped with the reports on the working of an 'Otto' gas-engine and the heating of large roasting-ovens by Dowson Gas at South Kensington, at p. 112. (Plate 65.)

D. K. CLARK.

IV. REPORT ON TESTS OF STEAM BOILER APPLIANCES.

No. 1. J. Hampton.—Fire-proof Smoke-Consuming Bridge: a hollow bridge of cast-iron, sloping backwards towards the flue. The lower part of the flue at the bridge, or back of the furnace, is closed by a cast-iron plate. To this plate is bolted the bearing-plate, which carries the upper or hollow part of the bridge forming the back of the furnace. This upper part is made in two pieces, for easy erection and easy removal. The front portion is made with numerous perforations, through which a supply of air from the interior—heated to a greater or less extent—is delivered in streams into the fire-place, to mingle with the gaseous products of combustion, for the purpose of consuming them. (Plate 70.)

This bridge was examined and tested at the works of Messrs. Chidley, Phillips & Co., distillers, Stratford, on July 11, 1882, where it was at work on the steam boilers. The boiler to which attention was directed was a Cornish boiler, 7½ feet in diameter and 30 feet long, with a flue 2 feet 9 inches in diameter. The fire-grate was 6 feet in length. The smoke was considerably reduced by the employment of the bridge, in consequence of the admission of air from the bridge through the perforations, which were twenty-one in number and ⅝ inch in diameter. Nevertheless, it was necessary to keep open the fire-doors occasionally, in order to reduce the smoke, the small coal used being of a very smoky character. New bridges were in course of being substituted by Mr. Hampton, having fewer and smaller apertures; and it was stated that the performance of the boiler was improved by the substitution: evidence apparently that too much air had been admitted through the earlier bridges, so as to affect the supply of steam. The Hampton bridges have proved to be very durable wherever they have been erected.

No. 2. James Moore.—T. Nutt's 'Patent Economising and Smoke-consuming' Furnace. As applied to a Cornish boiler, there are four firebrick diaphragms built across the flue-tubes, dividing it into four compartments. The first diaphragm is built just behind the ordinary bridge at the back of the furnace, and is constructed with openings between the bricks at the upper part for the draught. The second diaphragm consists of a small steam boiler or tank, occupying the lower half of the flue, surmounted by a solid brick wall occupying the upper half. The small boiler is formed with an arch over the lower part of the flue, through which the draught passes. It is supplied automatically with water from a cistern at the front. The third diaphragm is solid for the lower half, and is made with numerous openings through the upper half for the draught. The fourth diaphragm, placed at the far end of the flue-tube, is made with openings through the lower half for draught. By such a disposition of diaphragms, the undulations of draught produced are conducive to intermixture and combustion. In addition, the steam from the small boiler in the second diaphragm is discharged in numerous small jets from a perforated pipe at the back of the small boiler, thus forcibly intermixing the elements. (Plate 71.)

This system was tested for smoke prevention on the Cornish boiler at Betts's saw-mill, Homerton. The boiler was 4½ feet in diameter and 18 feet long, having a flue-tube 2 feet 8 inches in diameter. The fire-grate was 5½ feet long. The door was

formed with six air-slots 4 inches by $\frac{3}{8}$ inch wide. Fired three times with common slack in the course of half an hour, the smoke, taken together, was visible for only $2\frac{1}{2}$ minutes. The deepest shade was No. 3 smoke-shade, except once, whilst a very heavy fire was charged, when smoke of No. 5 shade passed from the chimney, and entirely disappeared within $1\frac{1}{2}$ minutes.

From the reports of results of tests made, in May and June 1880, at the Western Pumping Station of the Metropolitan Board of Works, of No. 4 boiler, set on Mr. Moore's system, it appears that, whilst smoke was nearly all prevented, an evaporation of 8·88 lbs. of water supplied at 90° Fahr. per pound of coal was effected, and that an additional pumping duty of 20 per cent. was performed.

No. 3. Thomas Henderson.—Furnace-front and Fire-door. The door is balanced, and turns on a horizontal axis at the lower side. It is made with two leaves directed towards the furnace, by one of which the doorway is closed, whilst the other leaf is in a horizontal position, forming a continuation of the dead-plate. The door-leaf is hollow, air being admitted from below into the cavity, where it is partially warmed, and whence it is delivered through perforations in the inner plate into the furnace. The door can be adjusted on its axis to admit air into the furnace through the doorway and, at the same time, at the dead-plate. When the door is turned downwards—a movement which can be effected by a stroke of the shovel—the door-leaf may be lowered into a horizontal position level with the dead-plate, when the furnace can be stoked, after which the door is restored to its usual position. When it is required to clean the fire, the door is turned down still further—below the horizontal position—so as to present a sloping surface, upon which clinker and ash are received, and from which they are discharged into the ashpit, whilst the dead-plate leaf hangs as a screen, vertically downwards, and protects the stoker. The furnace-front is double, and is so constructed that currents of air pass through it, and are delivered warm into the furnace. (Plate 71.)

This apparatus was tested for smoke, June 23, 1882, at the works of Messrs. Wright & Co., Wharf Foundry, Bolton, where it was applied to one of the steam boilers. The boiler was $6\frac{1}{2}$ feet in diameter, having two flue-tubes $2\frac{1}{2}$ feet in diameter. The grates were 6 feet long. The steam pressure was 45 lbs. per square inch. The fuel used was slack, consumed usually at the rate of 6 cwt. per hour. Smoke, usually of from No. 6 to No. 7 smoke-shade, was discharged after every levelling and firing, whilst the door was set open as much as one inch on each occasion. The smoke cleared off in from one to three minutes after firing. As firing took place ten or eleven times per hour, the total duration of smoke was at least 20 minutes in the hour.

No. 4. R. W. Crosthwaite.—C. B. Gregory's Smoke-Burning Furnace applied to Cochran & Co.'s Vertical Boiler: an adaptation of Gregory's furnace already described (p. 55) for generating steam. Cochran & Co.'s boiler is constructed with a semi-spherical fire-box, 3 feet in diameter at the fire-grate, from which, at one side, the products of combustion pass into a combustion-chamber above, thence through a number of horizontal flue-tubes into the smoke-box and the chimney. The ashpit was thoroughly closed for the purpose of the trial; and the flue from Gregory's furnace was conducted into the fire-box of the boiler, through the doorway, which was curtailed by firebrick to form a passage-way 9 inches wide by 2 inches high. The fire-grate of the Gregory furnace was $17\frac{1}{2}$ inches by $8\frac{3}{4}$ inches, and the throat, or way out, was $17\frac{1}{2}$ inches by $1\frac{1}{2}$ inch. Two streams of heated air entered the throat at opposite sides, through openings $17\frac{1}{2}$ inches by 1 inch high. (See Adaptation to a Lancashire Boiler, Plate 19.)

Two days' tests were made. On the first day, the apparatus and the boiler were tested together; the second day, Gregory's furnace was disconnected, and the boiler was tested in its ordinary condition. The fuel consumed was Silkstone coal. The following are the leading results (Table XXXIII.):—

TABLE XXXIII.—GREGORY'S FURNACE FOR STEAM BOILERS *versus* THE ORDINARY BOILER.

Data	Gregory furnace connected to boiler	Ordinary boiler
Date of test	May 1, 1882	May 2, 1882
Duration of test	8 hours	8 hrs. 21 min.
Coal consumed	188¼ lb.	229½ lb.
Do. do. per hour	23·56 lb.	27·50 lb.
Clinker	½ lb.	2½ lb.
Ash	25¼ lb.	5 lb.
Feed water, temperature	67·5° Fahr.	62° Fahr.
Do. consumed	19 cub. ft. 1185·6 lb.	19 cub. ft. 1185·6 lb.
Do. consumed per hour	2·375 cub. ft.	2·28 cub. ft.
Do. per lb. of coal	6·29 lb.	5·17 lb.
Period during which smoke was visible	18 min.	6 hrs. 40 min.
Maximum smoke-shade	No. 1	No. 8
Average smoke-shade for the whole period of trial	0·04	2·86

These results show practically an entire freedom from smoke for the Gregory furnace, and for the boiler with the ordinary furnace an average smoke-shade nearly No. 3, whilst the maximum was No. 8. The quantity of water evaporated per pound of coal with the Gregory furnace was upwards of 20 per cent. more than without it.

No. 5. THOMAS HENDERSON.—Mechanical Stoker: for firing small coal or slack. The slack is charged into a hopper, in which it is crushed, as required, and carried downwards by a revolving toothed roller, which beats opposite a pressure-plate. The width of the clearance between the roller and the plate is regulated by means of a screw, for the purpose of regulating the feed of coal to the furnace. The coal is dropped upon two horizontal fans or propellers, formed with fins, by which the fuel is propelled into the furnace upon the fire-grate. The fans are caused to revolve on vertical spindles, by friction-wheels, which are below them and support them; the wheels being keyed on a horizontal transverse shaft driven by means of worms and worm-wheels, by power from a small engine, placed near the boiler. The furnace-bars are reciprocated by means of a rocking crank-motion, in which there are two sets of cranks at right angles. Whilst every alternate bar rises and falls ⅜ inch above and ⅜ inch below the regular level, the intermediate bars have a longitudinal movement of 1 inch to and fro, in order to break up clinker as it is formed, and carry it backward over the bridge, and to cause the coal to travel backward as it burns. (Plate 72.)

Mr. Henderson's stoker is at work on several boilers at the Dean Clough Mills of Messrs. Crossley, Halifax. The boilers are 7½ feet in diameter, and 23½ feet in length, having two flues 3 feet in diameter. The grates are 3 feet 10 inches in length, having a combined area of 23 square feet. It is stated that 5 tons per day of Charlston nut-slack can be burned off; but that 3½ tons is as much as can properly be consumed in a day of 9½ hours, being at the rate of nearly 7½ cwt. per hour. From official returns of the results of special tests at Dean Clough Mills it appears that 6·70 lbs. of water was evaporated per pound of nut-coal from the temperature of 50° F. into steam of 70 lbs. pressure per square inch, by hand-firing; and that 8·31 lbs. of water was evaporated per pound of nut-coal from the temperature 184° F. into steam of the same pressure, with the mechanical stoker. Making due allowance for the higher temperature of the feed-water, the equivalent quantity of water evaporated from 50° F., with the mechanical stoker, is 7·10 lbs. per pound of coal, being 6 per cent. more than was evaporated with hand-firing.

Henderson's mechanical stokers, at work on the three Cornish boilers at the Surrey

engine-house of the Surrey Commercial Dock, Rotherhithe, were tested for smoke-prevention, July 7, 1882. The boilers are 5¾ feet in diameter, and 25 feet long, having each one flue 3¼ feet in diameter. The fire-bars are 4 feet 8 inches long, making 15 square feet of area. The pressure of steam was 80 lbs. per square inch. Observations were made for one hour on the performance of one of the boilers. During that period 3¾ cwt. of small household-coal was burned off, being at the rate of 28 lbs. per square foot of fire-grate per hour. The rate of feed of the fuel was occasionally greater than could be accepted without forcing the fires, and causing a considerable evolution of smoke, the feed-apparatus appearing to be somewhat uncertain in action. In the course of one hour, the fire-doors were opened on six different occasions, for the purpose of dressing the fire by levelling the fuel, which lay mostly about the middle region, and throwing up the loose coal which collected on the dead-plate. The smoke-shade was usually No. 7 or No. 8 when the fire was thus manipulated. The total duration of smoke was 20 minutes in the course of the hour, and the average smoke-shade for that time was 3·7; and, averaged for the whole period of one hour, it was one-third of that shade, or 1·23.

No. 6. E. Bennis.—Mechanical Stoker: in which small coal or slack is scattered over the grate, from the front, by means of a shovel over the doorway:—six ounces of coal at a time. The shovel is actuated by helical springs, which are put in tension by means of a 4-cam shaft across the front of the boiler, of which the cams have four degrees of throw; so as to graduate the tension on the springs according to the length of trajection required. The fire-bars are caused to reciprocate by means of cams on a horizontal shaft across the front of the boiler, in such a manner that the bars are slid backward simultaneously into the fire-place, carrying the fuel with them; these remain stationary for a very short time; and are next drawn out, two at a time, without disturbing the fire. In moving inwards together, the fire-bars keep in one plane, rising slightly as they advance; the length of the travel being 1½ inch. In returning, each bar is lifted ⅛ inch at the camshaft, for a length of half an inch of the return travel, for the purpose of breaking up clinker; then the bars fall to the level, and complete the return travel. The fuel is fed by means of a crushing roller at the base of the hopper; the feed being regulated by reciprocating flaps. (Plate 73.)

Bennis's mechanical stoker is at work on the end one of a range of Lancashire steam boilers at the Hope Spinning Company's Mills, Failsworth, Lancashire. The boilers are 7 feet in diameter, and 30 feet long; having two flue-tubes 2 feet 9 inches in diameter. The boiler fitted with the stoker and the one next to it, fired by hand, were tested

Table XXXIV.—BENNIS'S MECHANICAL STOKER *versus* HAND-FIRING.

	Date of trial			
	June 22, 1882		June 28, 1882	
System of stoking	Mechanical	Hand-firing	Mechanical	Hand-firing
Time at work . . . . . hours	7	7	5¼	5¼
Fuel, description	Burgey	Burgey	Slack	Slack
Do. consumed . . . . . cwts.	54	60	42½	37
Do. do. per hour . . cwts.	7·71	8·57	8·10	7·05
Do. do. do. per square foot of grate . . . . . . lbs.	30·9	29·1	32·4	23·9
Feed-water, temperature . . Fahr.	100°	100°	104°	104°
Do. consumed . . . cub. ft.	872·6	829·7	763·1	527·2
Do. do. per hour . cub. ft.	124·7	118·5	145·4	100·4
Do. per lb. of coal . . . lbs.	8·95	7·66	9·94	7·89
Do. do. equivalent from and at 212° Fahr. . . . . lbs.	10·29	8·81	11·33	8·90

together, for rate of combustion and evaporative efficiency. Two several tests were made of each boiler: the first day, burning burgey, or coal in small pieces, as large as, or a little larger than, walnuts; the second day, burning slack. The fire-grates of the first boiler were 5 feet 2 inches long, and had a combined area of 28 square feet. Those of the second boiler, hand-firing, were 6 feet long, having a combined area of 33 square feet. The principal results of the two days' tests are given in Table XXXIV. The feed-water was in every instance passed through Green's Economiser, and was delivered to the boilers at a temperature of about 200° F.

The foregoing results show greater quantities of water evaporated per hour by the mechanical stoker than by hand-firing: by 5 per cent. on the first day, and 45 per cent. on the second day. Likewise, a greater evaporative efficiency with the mechanical stoker: by 17 per cent. on the first day, and 26 per cent. on the second day. It appeared that burgey was not so well suited for the operations of the mechanical stoker as slack—probably because it was more clinkery than the slack. On the first day, it was necessary to dress the fire of the mechanical stoker about twice an hour; loosening the clinker, and throwing on the fire the loose coal that dropped at the dead-plate. The hand-firing boiler required to be thoroughly cleared of clinker, and remade, in the middle of the trial, though it had been cleaned just before the trial was commenced. As the burnt gases from several boilers were delivered into one chimney, there was not an opportunity of observing the smoke-shades, if there were any, from the mechanical stoker. But it happened, occasionally, that the chimney was quite clear of smoke; and it was argued that, as the mechanical stoker worked under uniform conditions, if it was clear of smoke at any time, it must always have been clear of smoke. It remains unascertained whether the occasional dressing that was necessary did or did not raise any smoke.

No. 7. The Chadderton Ironworks Company.—McDougall's Mechanical Stoker: feeding the fuel by pushing it into the furnace, and carrying it back by means of reciprocating fire-bars. The fuel descends from a hopper by gravitation, and is pushed in upon and over the coking-plate by the agency of a ram, to which a reciprocating movement is communicated, by means of an excentric on a transverse shaft, and a lever which is slotted so that the travel of the ram may be varied. The ram is of less depth at the middle than at the sides, in order that the greater proportion of the fuel may be delivered next the sides of the furnace. The feed of the fuel is also adjusted by means of a vertical sliding-plate. The coking-plate, upon which the fuel is first deposited, projects a short distance into the furnace, to facilitate coking; and it is provided with apertures for the admission of air, to ignite the fuel before it reaches the bars. All the fire-bars are movable; they are supported at their outer ends on a transverse shaft, consisting of a series of cranks or excentrics having a throw of half an inch, turned out of a solid bar of steel on three centres pitched at angles 120 degrees apart. Each bar is carried by its own excentric, and its motion is one-third of a revolution before or after that of each of the contiguous bars. The bars thus acquire a compound longitudinal and vertical movement at the front, whilst their inner ends rest on a bevilled cast-iron bridge, rising as they advance inwards, and the neighbouring bars falling as they are drawn outwards. By these combined movements of the bars the fuel is carried inwards, and the clinker is broken. The motion of the 'eccentricated shaft' is derived from pulleys of three speeds. (Plate 74.)

McDougall's Stoker was tested, July 1, 1882, at the Crescent Bleach Works, Salford, on one of a number of steam boilers there. The boiler was 7½ feet in diameter and 30 feet long; having two flue-tubes, 3 feet in diameter, with grates 5 feet 2½ inches in length, making a combined area of 31¼ square feet of grate. The trial lasted six hours, during which time 28 cwt. of slack was consumed, being at the rate of 4⅔ cwt. per hour, or 16·7 lbs. per square foot of grate-area per hour. Of feed-water, 457·3 cubic feet was evaporated at atmospheric pressure, being at the rate of 76·22 cubic feet per hour, or

9·10 lbs. per pound of slack from 57° F., equivalent to 10·56 lbs. per pound of slack, from and at 212° F.

The fires required a considerable degree of attention. They required to be opened up eleven times in the course of six hours, or every half an hour, arising probably from the fact that the rate of feed was excessive in relation to the capacity of the fire-bars for carrying forward the fuel. The doorway became clogged with slack, and the feed of fuel was suspended several times, making together 100 minutes of rest for the left-hand feed and 50 minutes for the right-hand feed. Yet the fires were bright near the back of the furnace. The deficiency of the carrying power of the fire-bars may be accounted for by their very limited traverse, only ½ inch to and fro—the shortest travel that has come under notice in the course of the tests of Mechanical Stokers.

The eccentric bearings for the fire-bars, exposed to a considerably high temperature, required to be greased at intervals of three-quarters of an hour.

Benjamin Goodfellow.—Johnson's Smoke and Fume Washer was exhibited in model. It was tested, June 28, 1882, at the works of the exhibitor, Hyde, for smoke prevention only. The apparatus consists of an enlarged flue through which the products of combustion pass on their way to the chimney. It is made of strong timber, put together airtight. The lower part of the flue is a water-tank divided into compartments, each of which contains a dash-wheel, like a paddle-wheel, having a number of spikes or prongs fixed on each block at the circumference. As the wheels revolve, the prongs are dipped into the water in such a manner as to raise a continual spray, which is traversed by the current of smoke, and by which the smoke is washed. Each wheel is succeeded by a screen composed of coke, laths, or other suitable material, through which the current passes, and by which every solid particle is arrested. By means of a fan placed beyond the screens, the draught is maintained undiminished.

By the operation of the smoke washer, the smoke current was cleansed of all solid particles, and was lightened in shade to a material extent, issuing from the chimney of the apparatus, of a bluish colour.

It has been ascertained by Mr. Estcourt, the City Analyst, Manchester, that when water alone is used in the apparatus, a proportion of from 75 to 80 per cent. of the sulphurous acid gas is intercepted; and that, by dissolving soda or lime in the water, the whole of the acid can be taken up.

The object of the invention is chiefly to intercept the sulphurous gas from smoke, and to prevent poisonous impurity escaping into the atmosphere.

REMARKS ON STEAM BOILER APPLIANCES.

J. Hampton's Fireproof Bridge is distinguished chiefly for its durability. James Moore's Perforated Firebrick Partitions have no doubt proved instrumental in not only diminishing smoke but also in economising fuel by increasing the evaporative efficiency. These results clearly follow from the means provided for mixing the currents of combustible gases and air, and the partial detention of the hot gases between the partitions. Thomas Henderson's Furnace-front and Fire-door are conveniently worked, and are especially serviceable on board steamships, where the balanced door remains in one position irrespective of the movements of the vessel. R. W. Crosthwaite's exhibit of Mr. Gregory's application of his furnace to a steam-boiler supplied powerful evidence, if such had been necessary, after the evidence previously accumulated, of the soundness of Mr. Gregory's system of smoke-burning furnace, in the absolute freedom from smoke after the fire was got into working condition; the very slight appearance of smoke even at the commencement; and the complete combustion with a very limited surplus of air.

Thomas Henderson's Mechanical Stoker appears to have been defective in unequally distributing the fuel over the fire, involving the frequent opening of the door and dressing

of the fire. It could not, according to the results of the test, be forced without discharging a considerable degree of smoke at the chimney. E. BENNIS's Mechanical Stoker was worked with a fire-bar movement by which the advance of the fuel and the clinker towards the bridge was ensured; at the same time that the fuel was spread with a fair degree of uniformity where it was required. In consequence of such regularity of action, this stoker made a remarkably high percentage of economy of fuel and efficiency of evaporation compared with the performance by hand-firing. The performance of the CHADDERTON IRONWORKS COMPANY'S Mechanical Stoker, by Mr. McDougall, appears to have suffered by the very limited traverse of the fire-bars, which was only half an inch, and the apparent inability to carry inwards the fuel, and carry off the clinker with sufficient rapidity.

The limitation of the traversing movement to half an inch incurred a want of due proportion between the coal-feeding power of the ram and the conveying power of the grate. It appears to be incident to the construction of the 'eccentricated shaft,' which, as a shaft, could not conveniently be made of a much greater degree of eccentricity. These conditions imposed the necessity for very frequent manipulation of the fire-place. The frequent lubrication required by the eccentricated shaft and the ends of the fire-bars indicated a liability to wear, by which the length of traverse of the fire-bars must be gradually reduced—a reduction which could not well be afforded where the traverse originally is very short.

D. K. CLARK.

V. REPORT ON FURNACE FOR GENERAL HEATING PURPOSES.

MICHEL PERRET exhibited a furnace—the Multiple-Staged Furnace—well designed for the purpose of thoroughly consuming any kind of fuel, and particularly adapted for the combustion of refuse and wasted fuel, even such as may discharge 30 per cent. or 40 per cent. of ash. (Plate 75.)

The furnace consists of a cubical chamber of brickwork containing a series of firebrick shelves, one above another, upon which the fuel is spread, and is gradually consumed. The chamber is 3·28 feet wide, by 6 feet by 4·10 feet. There are four shelves, each 5 feet long, being 1 foot shorter than the furnace-chamber. They reach from the front and the back alternately, and the fuel may be lowered from one to another successively. The furnace is, in the first place, heated to a red heat by burning wood on all the shelves, as well as in the ashpit; then each shelf receives a first charge of the fuel. At the proper time, the fuel is lowered by means of suitable fireirons, introduced through doorways in the front of the furnace, from each shelf to the shelf below it, on which it is evenly spread; and the uppermost shelf, now empty, receives a fresh charge of fuel. This process of arranging and charging the furnace is repeated at intervals of twenty-four, twelve, or six hours, according to the strength of the heat required. The rate of combustion is as follows:—

24 hours interval	. . . . .	0·41 lbs. fuel	per square foot	per hour
12 „	. . . . .	0·82 lbs.	„	„
6 „	. . . . .	1·64 lbs.	„	„

These quantities are taken as for pure fuel, ashes excluded. The quantity of air admitted is regulated to a nice degree of exactness. It is heated to 570° F., it may be, and is admitted exclusively at the entrance to the ashpit. The Perret furnace is successfully at work in many places: for evaporating liquids, for stoves of all kinds, and for heating-apparatus.

The Perret furnace, for want of suitable conveniences, was but partially tested. Its merits as a generator of heat, and a supporter of high temperature, with complete combustion of fuel, without smoke, were in daily evidence during the Exhibitions at South Kensington and in Manchester.

D. K. CLARK.

VI. REPORT ON TESTS OF ACCESSORY EXHIBITS.

1. JOSEPH KERSHAW & Co.'s Non-conducting Composition for coating steam boilers, pipes, &c. The base is blue marl, which is treated with chemicals, and mixed with vegetable fibre. The composition was tested for non-conduction, June 30, 1882, at the works of the exhibitors, Hollinwood, near Manchester. Two cast-iron pipes, exact duplicates, were prepared for the purpose. They were 3 inches in diameter inside, and 3⅝ inches outside, and 5 feet 11½ inches long, closed and made steam-tight with a plate at each end. One of the pipes was bare, having only received a coat of black varnish. The other pipe was coated with the composition, $2\frac{1}{16}$ inches thick, making up the external diameter to 7¾ inches. The pipes were laid, in the open air, at a height of 4½ feet above the ground, parallel to each other, about 3½ feet apart, with a slight fall towards the outer ends, in order to collect and drain off the condensed steam. A slight shelter was erected above the pipes to place them in the shade; but there was free circulation for air. Steam, nominally of 30 lbs. pressure per square inch, was conducted from a vertical boiler, by a ½-inch tube, to the pipes, branched so as to carry equal and independent supplies to them, and connected to each of them through the end plate nearest to the boiler. This tube was thoroughly coated with composition, ½ inch thick, in order to prevent condensation in it, and that dry steam might be delivered to the pipes. The weather was sunny, mild, dry, with very little wind.

The test lasted exactly one hour. The pipes were thoroughly blown through and heated before the taps were closed; and the test was held to commence when the taps were closed. Steam from the boiler, having an average pressure of 28½ lbs. per square inch, was freely admitted to the pipes, and it was shut off at the end of one hour. The drain-taps were at the same time opened, and the water was collected from each pipe separately: from the bare pipe, 4 lbs. 10¼ oz.; from the coated pipe, 1 lb. 15¼ oz. The difference was 2 lbs. 11 oz.—the measure of the non-conducting property of the coating—making an economy of 58 per cent. of the steam condensed in the bare pipe. The temperature in the shade was 70° F., and that of the steam was 272°·3 F.; or 202°·3 above the atmospheric temperature. The loss of heat by conduction was measured by the latent heat—922·5 units per pound of steam condensed; and the total loss of heat was—

For the bare pipe . . . . 922½ units × 4·64 lbs. = 4,280 units of heat
„ coated pipe . . . . 922½ „ × 1·95 lbs. = 1,799 „

The external superficial area of each pipe was 5·62 square feet, and the loss of heat per square foot of surface was—

For the bare pipe . . . . 4,280 units ÷ 5·62 = 762 units
„ coated pipe . . . . 1,799 „ ÷ 5·62 = 320 „

Finally, the loss of heat per degree of the difference of temperature, 202°·3, was—

762 units ÷ 202·3 = 3°·77 per degree of difference of temperature per hour
320 „ ÷ 202·3 = 1°·58 „ „ „ „

2°·19 saving

This result—2°·19—as a measure of saving, exceeds what has been ascertained, elsewhere, by careful experiment.[1]

A few observations were made of the superficial temperatures at the outer surfaces of the bare pipe, and the coating of the other pipe, by placing ordinary boxwood thermometers, face downwards, upon them; also a thermometer on a metal plate, of which the bulb could be placed in contact with the surface. The following were the average results of several observations:—

	Bare pipe	Covered pipe	Difference
Boxwood thermometer . .	159½° F.	82° F.	77½° F.
Plate " . . .	195	88½	106½

When it is considered that the atmospheric temperature was 70°, the excess of temperature at the surface of the coated pipe—from 12° to 18½°—appears to be small. But these observations of temperature are only submitted as general indications of relative temperature.

2. JAMES STOTT & Co., Self-acting Gas-valve, or Governor. The object of this governor is to prevent over-pressure on gas-jets, and the waste which is caused by it; and what is required is an unvarying outlet-pressure, though there may be a varying inlet-pressure. A thin inverted cup or float, made of Barff's anti-corroding iron, dips into an annular porcelain trough of mercury formed with an inner shield for preventing loss of mercury, whatever may be the position of the instrument. The inverted cup is fixed on a vertical spindle, on the lower end of which a double-beat valve, having discs of equal diameter, is fixed, and on the upper end of which are placed the weights by which the valve is loaded. The pressure of the gas admitted by the inlet-pipe acts upon the inner surface of the cup. The cup, therefore, rises when the pressure of gas is augmented, and by the same movement the double-beat valve proportionally closes the thoroughfare for gas through the instrument, and, by wiredrawing the current, prevents the outlet-pressure from rising. When, on the contrary, the inlet-pressure falls, the cup falls, and the valves are opened wider; a proportionally larger current of gas is allowed to pass, and the outlet-pressure is prevented from falling. (Plate 75.)

This governor was tested, June 28, 1882, at the works of the exhibitors, Oldham. A 4-inch governor, suited for 800 lights, was tested at various inlet-pressures with one burner—Bray's No. 4 union jet, which consumes 4 cubic feet of gas per hour, under a pressure of 1 inch of water. It was tested also for 2 burners. The outlet-pressure was adjusted at 0·5 inch for an inlet-pressure of 1 inch.

4-INCH GOVERNOR.

Inlet-pressure	Outlet-pressure	Outlet-pressure
1 inch	1 burner, 0·5 inch	2 burners, 0·5 inch
1½ "	" 0·5 "	" 0·5 "
2 "	" 0·5 "	" 0·5 "
3 "	" 0·6 "	" 0·65 "
4 "	—	" 0·65 "

The next tests were made with a 1-inch governor on a 1-inch metre for 10 lights: first, under a constant inlet-pressure, with different numbers of lights; second, under varying inlet-pressures:—

1-INCH GOVERNOR.

Inlet-pressure	Burners	Outlet-pressure
3·6 inch	12	0·6 inch
" "	1	0·65 "
" "	12	0·625 "
" "	1	0·65 "

[1] See *A Manual of Rules, Tables, and Data for Mechanical Engineers*, by D. K. Clark, page 474.

1-INCH GOVERNOR—(*continued*).

Inlet-pressure	Burners	Outlet-pressure
1 inch bare	12	0·65 inch
2 inch	12	0·65 „
3 „	12	0·65 „
4 „	12	0·65 „
5 „	12	0·65 „
6 „	12	0·65 „
7 „	12	0·625 „
8 „	12	0·6 inch full
9 „	12	0·6 „
8 inch	2	0·7 inch bare
1 „	1	0·7 inch
2 „	1	0·7 „
3 „	1	0·7 „
4 „	1	0·7 „
5 „	1	0·7 „
6 „	1	0·7 „
8 „	1	0·7 „

The shop meter, a ¾-inch meter for 5 lights, was tested by lighting up all the jets in the workshop, 29 of No. 6 Bray's burners, together with a tinman's stove passing 15 cubic feet of gas per hour. Several of the lights were turned off successively, with the following results:—

¾-INCH SHOP METER.

Inlet-pressure	Burners	Outlet-pressure
2·4 inch	20, and stove	0·45 inch
2·4 „	12, and stove	0·50 „
2·4 „	1	0·55 „

This test was very severe: it was made with a meter that was stated to be adapted for only five lights. The loss of pressure by frictional resistance was considerable.

The results of the tests, above reported, prove that the scope of the Stott Governor is very wide, and that its control of the pressure is amply satisfactory.

D. K. CLARK.

REPORT OF MEETING

Held, by kind permission of the Duke of Westminster, at Grosvenor House, on Friday, July 14, 1882, for the purpose of receiving the Reports of the Committees and Jurors in connection with the Exhibitions and Tests at South Kensington and Manchester, and making Awards. Also to consider the advisability of giving a permanent character to the Movement by the formation of a Smoke Abatement Institution.

HIS GRACE THE DUKE OF WESTMINSTER, K.G., PRESIDED.

The meeting was largely attended, and among those who were present were—His Grace the Duke of Bedford; the Right Hon. Viscount Bridport; Lord Mount-Temple; the Right Hon. Lord Crewe; the Right Hon. Lord Talbot de Malahide; Sir D. Cooper, Bart.; Lady Grosvenor; Lady Goldsmid; the Right Hon. G. Cubitt, M.P.; the Right Hon. W. Lowther, M.P.; Mr. Ernest Hart; Captain Douglas Galton, C.B.; Professor Abel, F.R.S.; Professor Chandler Roberts, F.R.S.; Dr. Quain; Dr. Corfield; Captain T. B. Hathan, R.A.; Mr. T. W. Cutler; Captain A. N. Montgomery; Miss Shaw Lefevre; Miss Emily Shaw Lefevre; Mr. George Godwin, F.R.S.; Mr. W. R. E. Coles, C.E.; Dr. John Wheeler; Dr. E. T. Ensor; the Right Hon. W. Egerton, M.P.; Mrs. Bompas; Mrs. Wheeler; Mr. J. F. Wilson, F.R.S.; Mr. Maurice E. Pollard; the Rev. Harry Jones; Mr. J. Norman Lockyer, F.R.S.; Mr. A. Hinckes Bird; Mr. William Haughton, R.H.S.; Dr. B. Holt; Mr. Phillips (Manchester); Dr. Sutton (Oldham); Mr. Scott (Manchester); Mr. F. Ingoldsby; Dr. J. N. Vinen; the Rev. H. Leigh; the Rev. H. Mallett; Mr. W. Staunton; Miss Milne; Mrs. and Miss Moss; Mr. W. Ellis; Mrs. and Miss Wright; Mr. Charles Barrett; Mr. T. Barrett; Mr. and Mrs. Debenham; Mr. N. B. Dawkins; Mr. S. Wirkworth; Mr. and Mrs. Conway; Mr. and Mrs. Webster; Mr., Mrs., and Miss Schollelin; Mr. T. S. Marks; Dr. J. O. Rees, F.R.S.; E. Gwynne, Esq.; Miss Sharpe; E. C. Robins, Esq.; Mrs. Wilson; Mr. A. J. Ellis; Mr. D. Kinnear Clark; Mr. H. Thompson; Mr. W. Pitman; Mr. R. F. Whier; Mrs. Alldridge; Mr. L. Alldridge; Miss G. King; Mr. G. J. Wild; Mrs. E. F. Green; Mr. and Mrs. John Hullah; Mrs. Mark Hammond; Miss Lankester; Mr. J. Thompson; Mrs. Rathbone; Mr. R. Harris; Mr. George Shaw, C.C., &c.

The Exhibitors at the Smoke Abatement Exhibitions were also largely represented.

The CHAIRMAN said, before proceeding to the actual business of the meeting, he felt he ought almost to offer an apology for occupying the chair on that occasion, but perhaps this was not so necessary if those present were good enough to remember that he was the owner of many thousands of those grates and chimneys which, while they cheered and warmed many thousands of those millions who inhabited smoky towns, also dirtied and defiled the bodies and the houses of so many householders in this country. It was, therefore, perhaps not so inappropriate as it might seem that he should occupy

the chair on that occasion, and he welcomed all present there that day. He might say to Mr. Hart and to the Committee that he regretted that he had been able, through domestic circumstances, to do so little in helping them in the great object in which they were concerned. Considering the great and the thoroughly national importance of this subject, both as affecting the health and the comfort of millions of this country, of those who inhabit all the large towns, as affecting the arts, architecture, painting, decoration, and furniture, and also with regard to the great importance of this subject in its economic aspect, it must be a matter of great satisfaction to those who were interested in this question of the mitigation of a great evil, that the Exhibition, which had been held in the winter, had altogether been a very great success. Though it had not been in one sense very attractive, and could hardly compete with exhibitions of flowers, objects of art and industry, or cattle shows, which naturally attracted, from their inherent merits, great numbers of people, it was satisfactory to note that no less a number than 116,000 persons visited the Exhibition during the time it was open. Very great interest in the movement had been excited, as was shown by the present meeting. Mr. Hart would be able to tell them something as to the practical results. With regard to kitcheners, considerable progress had been made. The question of open grates was still, he might say, a great open question. A perfect open grate which, while it would give a cheerful fire, would consume its own smoke and economise the expenditure of fuel, had still to be invented, but as they intended, by the formation of an Association, to keep the subject before the public, and to stimulate inventors, they yet hoped that this dream of the future would ultimately be realised, and that the vast number of grates in all the large towns of England would at last be made to economise fuel, to give a cheerful light, and to consume their own smoke. His Grace said he did not know that it was too sanguine a wish to hope that, sooner or later, such a grate would come to the front. They, the Committee, believed that if those present would come forward and assist them in forming an Association, they would arrive at this and other much-desired results, and that when they did, they would be enabled to go to Parliament with some confidence, to make that compulsory which ought to be made compulsory, and unless this was so, he (the Duke) believed no good would be done. At present they were not able to recommend any such thing, but they hoped to be able to do so in the future. The work connected with the carrying out of this Exhibition had been a very arduous one, and had been well sustained by its founder, Mr. Ernest Hart, by Mr. Coles, who had given gratuitously all his time to the movement, by gentlemen of eminence in science, and others, and they needed greatly to invoke their most invaluable services in the future in keeping this matter before the public, and in carrying out the objects of the Association. They should ask them and the public generally to further that great national measure against what must be considered a most serious and depressing evil, but which, nevertheless, was capable of prevention. His Grace concluded by calling upon the Chairman of the Committee to present the Committee's Report.

Mr. Ernest Hart said, in presenting the General Report of the Smoke Abatement Committee, and the List of Awards, it would not, he thought, be necessary that he should read that Report, since the bulk of the Report consisted (as it almost necessarily must be in the case of such a document) of an historical recapitulation of that which had been done up to that time in the way of organisation; and the Report did not enter upon any speculative considerations, because they (the Committee) desired throughout this movement to state the facts as they presented themselves, and hoped not to promise more than they saw their way clearly to perform. In connection with the Smoke Abatement Exhibition, the Report would show that a large amount of actual work had been done, and it was the object of the Committee, from the first, that it should not be merely a display of objects of interest, but that the relative power of each invention to fulfil the purpose for which it was intended should, as far as practicable, be carefully tested by skilled experts, under conditions agreed upon with the Exhibitors.

The Committee did not pretend to say that every Exhibitor would feel satisfied with the results of the awards. It was, perhaps, not possible, however carefully the investigations might have been conducted, however great the precautions adopted, however eminent the persons who voluntarily gave their time, however skilled the paid officers—that all the results should be either strictly just to the Exhibitors, or that they should give complete satisfaction to the unsuccessful as well as to the successful Exhibitors. But this the Committee ventured to say, and he ventured to claim on their behalf what he believed would be readily accorded, that all that care, energy, and an earnest desire for justice could do—all that could be done to provide competent tests, and skilled persons to superintend and carry out the testings—had been done. For the first time in the history of this country, he believed, there had been carried out at that Exhibition a thorough, careful, and complete examination of the power in the first place of various forms of household grates (of which several millions were in use in this town alone), to produce economical combustion, and in the next place their relative influence in producing smoke. It was remarkable that in the history of this country so little attention had been given to the improvement of the domestic grate. He looked upon this as a tentative step, and he trusted that the results which he had then the honour to put before the Meeting would be taken as a first contribution towards the subject, which had now seriously engaged the scientific intellect of the country. The volume which he had the honour to present to the noble Chairman consisted of the Report of the jurors in each department. They included a very valuable series of documents, the result of some three hundred tests—not only mechanical tests carried out under the direction of the Executive Committee, by Mr. D. K. Clark, the testing engineer, but also that which had never before been attempted, namely, chemical tests of the flue-gases withdrawn from the chimneys of a great variety of domestic stoves and grates burning different descriptions of fuel. The attempt had been made in that way to determine in respect to each grate, not only the relative economy of fuel and the amount of heat given out, but also the character of the gases produced in combustion—an important factor, if the smoke abatement question was considered from its scientific as well as from its popular aspect. For this important series of testings they were indebted to Professor Chandler Roberts, F.R.S., of the Royal School of Mines, Chemist to the Mint, who, with the assistance of Professor Frankland, F.R.S., had devised and carried out an original method of applying known principles of chemistry to this purpose. The results—although they were only first results, and for which, he believed, Professor Chandler Roberts would not claim finality—were, nevertheless, in their character, of the most important and interesting kind, and they were greatly indebted to him for the active part he had taken in this matter. As to the result of the testings, in all the various classes, on which some of the jurors would themselves make a brief statement, he might say they had been upon the whole satisfactory to them. The Committee did not look upon anything that had been done as indicating the end of the work they had in view; they did not even regard the present use of solid fuel in the form of coal, or in any other solid form, as being the ultimate form in which fuel should be used to prevent the production of smoke in this country. Mr. Hart referred to Dr. Siemens' opinions as to the future of gaseous fuel, which, he said, was a much larger and more important field, and one to which they might look for the best fruit of their future labours. He should not be doing justice to the opinions and work of Dr. Siemens in this matter if he did not state distinctly that on that ground Dr. Siemens had stood aloof from the awarding of medals for apparatus intended for the use of crude coal for domestic and some other purposes. The Committee had, however, felt bound to recognise the value of improvements in such grates in the existing state of things. It had been a great satisfaction to them to see introduced at the South Kensington and at the Manchester Exhibitions a series of considerable improvements, many of them of quite recent date, and the direct outcome, so to speak, of the present movement, and many

of them extremely effective. They were told, when they commenced the formation of the Exhibition, that the first problem to solve was how to prevent kitcheners from smoking. Now there was not a house in this country in which it was not possible to employ a comparatively, if not a perfectly, smokeless kitchener, using either bituminous or anthracite coal or coke, for either could be used with economy and efficacy, without the production of visible smoke. As to open grates, the jurors would be able to tell them that there were a number of open grates of recent introduction, some based upon old and well-known principles, which were shown at the Exhibition, many of which were practically smokeless, or very nearly so, in which ordinary coal as well as anthracite coal might be burnt. The Siemens principle had given excellent results, and the gas-and-coke grates and kitcheners on this principle had been very successful in the testing-houses. Mr. Hart said it was especially to the gas section that they desired a large number of their friends to turn their attention, for they looked to that section as giving the largest promise of the fruits for which they looked, and the Report of the jurors of that section would be found of great and novel interest. As to the prospect of the movement being made more extensive, he said it was felt that if the Committee were to end their work with the Exhibition, and by the announcement of the awards, they could not hope for that lasting benefit which they trusted that this movement was destined to achieve. They had, therefore, after maturely considering the matter, determined, having received much encouragement in that view from the public and from eminent personages, socially and scientifically, to convert their Smoke Abatement Committee into a Smoke Abatement Association. This they were enabled to do by certain powers of the Board of Trade, which would limit the liability of each member to the amount of his annual subscription, or such other amount as the member might voluntarily choose to give. The following were stated to be the main objects for which the Association was to be formed:—

1. To promote the abatement of coal smoke, and other noxious products of combustion, in cities and other places, in order to render the atmosphere as pure and as pervious to sunlight as possible.

2. To check the present serious waste of coal, and the direct and indirect loss and damage accompanying the over-production of smoke and noxious products of combustion.

And to advance these objects more particularly in the following manner:—

(*a*) By calling public attention to the serious pecuniary loss, and injury to the health and comfort, which arise from coal smoke, and from defective heating, ventilating, and lighting arrangements.

(*b*) By stimulating, assisting, and encouraging inventors, manufacturers, traders, and others to bring forward, develop, and perfect, new or improved fuels, substances, methods, and appliances for the generation or application of heat or light, and for consuming or lessening the production of smoke and noxious products of combustion.

(*c*) By conducting practical trials of fuels, apparatus, and systems connected with the generation or application of heat or light, and causing reports to be made thereon for the guidance, assistance, or information of inventors, traders, intending users, and the public generally.

(*d*) By granting awards, certificates, medals, or prizes in connection with approved fuels, methods, or apparatus.

(*e*) By establishing, or assisting in establishing, public exhibitions, either periodical or otherwise, of appliances pertaining to heating, ventilating, or lighting.

(*f*) By collecting and recording statistics and information, and making, assisting, or encouraging experiments or researches as to the effects upon the atmosphere, and upon life, health, and property, of the use of coal and other fuels; and means employed or to be employed, in connection with heating and lighting.

(*g*) By imparting information, instruction, and assistance to local authorities, manufacturers, workmen, householders, servants, and the public generally, whether by means of

lectures, demonstrations, pamphlets, written articles, or otherwise, in relation to the subject of smoke prevention or abatement.

(*h*) By joining or concurring with any other institution, society, or persons, in doing, or causing, or procuring to be done, any of the things aforesaid, or to promote legislation and parochial and other regulations, or to assist in the enforcement thereof, and of any existing or future legislation, parochial or other regulations.

To do all such other things as may be incidental, or conducive, to the attainment of the above objects, or any of them.

This, the programme of their work in future, would, he hoped, serve to qualify any view which his hearers took of their shortcomings in the past; and the work which had been thought good in the past would, he hoped, lead to still better work in the futnre.

Mr. HERBERT PHILIPS (of Manchester), in the absence of Mr. Greg, Chairman of the Executive Committee, presented the Report of the Manchester Exhibition. He had, he said, received a commnnication from Mr. Greg, expressing his great regret at being unable to attend, and his sense of the great importance of the work of the Committee, as it affected Manchester and all other mannfacturing towns, and the large amount of good which the influence of the Duke of Westminster must produce on the movement. The Report referred to the Smoke Abatement Exhibition held at Manchester in the latter end of April and the beginning of May, which was distinctly the outcome of the Exhibition held at South Kensington. The Association for the Control of Noxious Vapours of Manchester had entered into communication with the Committee, and Mr. Greg had consulted with Mr. Ernest Hart, the Chairman, and Mr. Coles, the Hon. Secretary, of the South Kensington Exhibition, on the matter. Accordingly, at the close of the London Exhibition overtures were received at Manchester to open the Exhibition there. This they had the conrage to do, not sure of the amount of assistance they shonld receive from the Corporation of Manchester. He might say, however, that they had received great assistance from the Mayor and other members of the Association. The Exhibition was one of great importance. They all knew the unenviable reputation which Manchester enjoyed for its peculiarly foul atmosphere; it was also the centre of a number of manufacturing towns, all of them more or less suffering in the same way, and the mayors of which were members of the Committee, the combined population being not less than two millions. The attendance at the Manchester Exhibition had on the whole been very fair; in all 32,000 persons had visited the Exhibition in the course of the month during which it was open. The Exhibition followed generally the same lines as the one in London, a great number of exhibits having been received at Manchester in an unaltered form, but in some cases they represented improvements on the London exhibits, which had been decided upon by the exhibitors in the interval. There was a good deal of prominence given to the various modes of feeding a fire, and also to the apparatus of manufactories, which naturally received a greater degree of prominence and attention at the Manchester Exhibition than it did in London. The tests which were conducted were in a sense a continuation of the London tests. The Exhibition, in its financial resnlt, was so far successfnl that they would not be obliged to make any call upon the guarantors, though it would probably be found that they had not secured a profit. During the progress of the Exhibition there were lectures delivered by eminent scientific men on subjects bearing on the objects of the Exhibition, which created a considerable amount of interest, and he had reason to believe were instructive to those who heard them. There were also articles and reports published in the paper which was established in connection with the Exhibition, and the local press took a good deal of notice of the Exhibition during its progress. He mentioned as among one of the pleasing featnres of interest created in the Exhibition, that a good many of the leading clergy at Manchester seemed to regard it with peculiar satisfaction; they coming in contact, as they did, with the poorest class of the inhabitants of Manchester, felt very strongly what a great evil it was

that smoke should prevent the introduction into districts most thickly inhabited of trees and open spaces where flowers could be grown. If the atmosphere of a town like Manchester could not be absolutely pure, it was not, he thought, too much to ask that the amount of vegetation which the Londoners were permitted to enjoy might be secured for the inhabitants of Manchester.

The presentation of the awards was kindly undertaken by Lady Grosvenor.

Mr. Harris, the Chairman of the Jurors in the Gas Section, made a statement on the more important conclusions of his Report, and said the Committee had been led to consider this section as a very important one. They considered that there was a large field open for gas-heating in connection with cooking; that being the case, special attention was invited at the Exhibition for the display of stoves adapted for cooking and heating, and also for manufacturing purposes. Those who had had the opportunity of visiting the Exhibition would recollect that a very large proportion of the space allotted was given up to stoves of that description, and that very great care and thought seemed to have been bestowed on the exhibits there shown. A careful examination was made of all the stoves, and it was thought desirable, in determining to whom the awards should be given, that these stoves should be divided into three or four classes. It was decided that there should be a class of awards for cooking-stoves, another for heating-stoves, and another for gas applied for manufacturing purposes. Gas applied for manufacturing purposes was the only sub-section to which it had been considered desirable that a gold medal should be given; that gold medal was given to Messrs. Thompson Brothers, of Leeds, for a very useful and effective furnace in which gas fuel was used for burning glass and pottery ware. It was given in this section, because it was considered that the application of gas for this particular purpose was entirely a new departure, and likely to supply a very large and important want, viz. the means of carrying on manufactories without the production of smoke; and by its means the operations would be carried on with much greater rapidity and efficiency than in the ordinary form of stoves. Another application of the same principle was that to baking-ovens; inasmuch as the baking of bread was a universal demand, there must of necessity be a large number of bakers and bakers'-ovens, and they produced a large amonnt of smoke in London, and if this application could be applied, at one swoop a large amount of smoke would be done away with. Then as to cooking-stoves, there was a very large display; practical tests were made, and awards were given in proportion to the value of the stoves, so far as the jurors were able to judge them. The cooking was supervised by the Lady Superintendent of the National School of Cookery, to whom they were much indebted, and it was evident from the results that a very great advance had been made in the department of gas cooking-stoves; the general conclusion being that the viands cooked by means of gas were certainly in no way inferior to, if not better than, the viands cooked by the ordinary way. The next department, which was very efficiently represented, was the application of gas to heating-stoves. They all knew that there was an objection to heating our rooms with stoves of a close character; this would probably somewhat stand in the way, but as a rule these gave very cheerful results, and would not make them regret the absence of their ordinary English coal.

Professor Chandler Roberts, speaking as one of the jurors in the section of steam-boiler appliances and furnaces, said the mechanical stokers and other appliances of which this class was composed were of special interest, as it was by their aid that the first efforts to abate the nuisance arising from smoke were made. Early in the present centnry Professor Faraday made some very important investigations, and the result of his and other investigations laid before a Select Committee of the House of Commons gave a great impetus to the work the Committee were now endeavouring to carry on. The appliances of this class might be divided into two divisions, those in which finely-divided fuel is scattered over a mass of incandescent fuel, and those in which fuel in a finely-divided state is forced on to a mass of burning fuel. Nearly every known

representative of these various types was exhibited, and many of them admirably performed their work. The jury had not considered any particular appliance of sufficient novelty to merit a gold medal, but he might mention as deserving of special commendation the appliance of Mr. Sinclair, of Leith, which was remarkable for its simplicity, and that of Messrs. Vicars, of Liverpool, which met every contingency that was likely to arise in practice. When they remembered that the cloud which hung over London contained every day about sixty tons of carbon, it was important to know, as they most certainly could, that at least boiler furnaces need smoke no longer.

Captain GALTON said he had been asked to explain why the Executive Committee of the Smoke Abatement Society selected certain exhibits for receiving the Siemens' medal. It would be in their recollection that Dr. Siemens offered 100 guineas to be given at the discretion of the Executive Committee. They thought, therefore, that it was best to select certain objects which would be entirely in unison with the principles of what Dr. Siemens had himself invented in the matter of smoke abatement. The two exhibits they had taken were the Falkirk Iron Company's double-oven close range, and the Dowson gas generator. The Falkirk Iron Company's range was heated on Dr. Siemens' principle with coke and gas, and the peculiarity of it was that both the air and the gas were heated by means of the gills at the back of the furnace, so as to adopt Dr. Siemens' regenerative principle. As to the Dowson gas producer, he might mention that it produced gas at a cost of about fourpence per 1,000 cubic feet, but this gas was very inferior in heating power to the ordinary gas, and was not, of course, in any way applicable to many purposes; but for heating purposes, the amount of gas which was consumed in the experiments which were made, as compared with that of coal gas, was four times the quantity; but, taking the respective prices of coal-gas at three shillings and Dowson's at fourpence per 1,000 cubic feet, it followed that the cost of Dowson's gas would be very much cheaper than that of coal-gas. With regard to its motive power in engines, practically very much the same results were obtained.

Mr. ERNEST HART stated, in respect to the Ladies' Prize, consisting of 100 guineas, to be divided between kitcheners and open grates, that the kitcheners had alone come up to that high standard which the ladies had in view, and this prize of 50 guineas it had been decided to divide between Mr. T. J. Constantine and the Eagle Range Company. The competition in respect to open grates would still remain open.

Miss EMILY SHAW LEFEVRE kindly undertook to present the ladies' prizes, and said she had been asked by the ladies of the Committee to express their great interest in the movement.

Mr. W. R. E. COLES announced that the Society of Arts' medal, which Lord Alfred Churchill, who was unavoidably prevented from attending, was to have presented, had been awarded to Mr. C. B. Gregory, of New Jersey, for his smoke-burning furnace, and stated that some important exhibits had been received from abroad, owing to the assistance rendered by the Secretary of State for Foreign Affairs in bringing the particulars of the Exhibition before the chief Foreign Governments. The Meeting would not be surprised to hear that a successful Exhibitor had come from the United States of America, and he (Mr. Coles) was enabled to say that the principle, which Mr. Gregory had shown at the Exhibition at South Kensington in a crude form, had, in the short interval since, been so far developed that it had, at the present time, been most successfully applied to a stove, a kitchener, and a boiler furnace. This, he thought, showed practically the goodness of the work in which they were engaged.

Lady GROSVENOR having completed the presentation of the awards in connection with the South Kensington Exhibition,

Mr. ERNEST HART, speaking on the subject of the Manchester awards, said the Committee of the Manchester Exhibition had done them the honour to approve of the methods of testing which the London Committee had adopted, after carefully examining those methods, and they had had the opportunity of observing the great care, the skill,

and the labour devoted to that task by their testing engineer, Mr. D. Kinnear Clark. The Manchester Committee had done them and him the honour of appointing him their testing engineer. The awards of the Manchester jurors had therefore been made on the same uniform plans as those adopted in London, and the medals were to be presented by their Committee at the request of the Manchester Committee, who had throughout not only carried out this enterprise with their characteristic energy, but with the utmost possible discretion, which was also very characteristic. They had to thank them throughout, not only for their energy, but for the great kindness they had shown their Committee in the matter, and he was sure the Exhibitors would say, for the great ability with which that Exhibition had been carried through.

Professor ABEL, in rising to move the first resolution, said Mr. Hart had put before them very clearly the work which the proposed Institution had to accomplish. This work, commenced systematically, had for the last two years been most successfully carried on by the Smoke Abatement Committee. Individuals who in this and other directions had made themselves eminent had from time to time worked energetically and successfully in the direction of the economic and efficient application of fuel. It was, he said, just one hundred years ago that Count Rumford, whose name was connected with so many important subjects, successfully worked in this direction. It was, he believed, not long after that Faraday produced the results to which Professor Chandler Roberts had referred. It was nearly half a century ago that Dr. Arnott produced a stove which was really the foundation of the most successful stoves of the present day; and twenty-five years ago Captain Galton gave them the grate which stood high in public estimation at the Exhibition at South Kensington. The community at large, if it had not exactly shown apathy in the subject, had, from the want of leaders, not shown that amount of energy in respect to the abatement of smoke or the more economical application of fuel. It was evident that the Committee had very important work to perform in that direction; work which had only been commenced; work, the nature of which had only been indicated by the past labours of the Smoke Abatement Committee. The recent Exhibition was for a time a source of instruction to all, not only in reference to the exhibits themselves, but as indicating how they should set to work to accomplish that which had only as yet been foreshadowed—the thorough application of gaseous fuel to heating purposes as an auxiliary to cooking. Some important improvements had been made in the direction of gaseous fuel applied to gas heating and cooking-stoves. Because the electric light was coming more and more into use, the gas companies need not despair of a great future, as gas might be applied for heating and cooking purposes; it was beginning to become a reality among them, and its economy was being felt. It had a great future before it in its application to cooking and heating purposes. There were directions in which they had not yet attempted to work. But there was another question, viz. the waste of fuel in the coalpits of this country, where an enormous mass of small coal was left underground, which it did not pay, at the present time, to bring to the surface. That coal would in the future, he was sure, be productive of gaseous fuel, and he felt sure that we should have not only a more efficient application of fuel, but we should have in these and other directions a vast economy in the application of fuel to domestic purposes. There was another point he might mention in the application of gaseous fuel. However perfectly they might burn coal, and however perfectly they might consume the smoke in the burning, they could not do away with the production of sulphur compounds, which were their most dangerous enemy. If they used fuel in a gaseous form, they had at once and readily fuel free from these substances, which were most destructive to furniture and to ornamental things, and most injurious to life and health. He thought they would all see that they had a vast amount of work before them, and it was with very great pleasure that he proposed the first resolution, 'That it is desirable that the work thus far successfully carried on by the Smoke Abatement Committee be continued, and for that purpose a Smoke Abatement Institution be formed.'

Mr. Norman Lockyer said he had very great pleasure in seconding the resolution which had been proposed in such an admirable way by Professor Abel. It seemed to him that having so far put their hand to the plough, they should not look back? Were all those economical benefits, those salutary benefits to science and art—were all these to vanish for the want of some such an organisation as that now proposed, without which there would be no means of influencing public opinion at the present time, or of influencing the Legislature in the future? The economic aspect which had been referred to probably could not be estimated in pounds at the present moment, but undoubtedly it was one which could be established by a careful series of statistics, such as an organisation like the one proposed could gather. When they had these statistics put before them, then the benefits to be derived from such an organisation would clearly establish themselves. But on scientific grounds there were many points of view from which they might see that the country had already suffered to an enormous extent from the absence of such an organisation, and that this country would certainly derive the greatest benefits from it in the future. It was a part of his official work day by day to observe the sun, but he was sorry to say that this smoke-cloud which continually hung over London brought about such a condition of things that observations could very often not be performed more than once a week, sometimes not even once a month. Mr. Lockyer concluded by referring to the great influence which the sun exercised upon our lives, our happiness, and our health. A sunless place was a joyless place. He, for one, believed in the great benefits to be derived from such an organisation as that proposed, and had great pleasure in seconding the resolution.

The resolution was then put to the meeting, and unanimously approved.

Lord Mount-Temple said that by the popular mind science was generally looked upon as a thing that had no practical bearing upon ordinary life, and that though it was a thing to be viewed with great respect and diffidence, it did not particularly affect the affairs of domestic life. Now he was very glad to see that science had condescended to come down to the chimney-corner and the fire-side hearth; and immense would be the benefits. He thought the proprietors of houses would be glad to take advantage of these elaborate scientific examinations, and their cooks and their housemaids would be acquiring a little of this sanitary science. He was glad to hear that the prejudice against close stoves was likely soon to be removed, and that the kitcheners were so good that there was very great difficulty in deciding which should be placed first. The noble lord referred to our unsatisfactory mode of ventilating rooms. He was, he said, also pleased to hear that the meat cooked by gas was in no way inferior to that cooked by the common fuel. The resolution which he had the pleasure of proposing was, 'That the best thanks of this meeting are due, and are hereby tendered, to the members of the Smoke Abatement Committee, to the Executive Committee, to the jurors and officers of the recent Smoke Abatement Exhibition.' Since the Committee had approached the subject they had found such wide support and so much co-operation, as to justify the continuation of the work so successfully begun. It would be a great pity, he thought, if it were now allowed to stop; and they had to thank the members, and particularly those jurors and officers who had brought all their knowledge to bear upon the subject. They hoped in the future they would give them as much aid, and produce such good results, as they had in the past; that they would organise and carry on the work which had been so well begun, and encourage invention, as he really thought inventors were just the people who wanted encouragement—men whose minds were full of intelligent and skilful ideas, and who could not find the capital or assistance which was necessary to bring them to utility.

The resolution on being put to the meeting was carried unanimously.

The Rev. Harry Jones said there was one great advantage in smoke. There was a familiar proverb which said, there is no smoke without fire, and he looked upon the present meeting as smoke, and as indicative of the fire of progress which would inevitably

result in the extension of this most valuable Smoke Abatement Society. He lived in the East End of London, and he need not tell them that they in the East End produced a great deal of smoke, and that during that time of the year, when most fires were burning, the wind was generally in the East, and the smoke found its way to the West; and they found that the West was equally a sinner in this respect, for everybody knew that it was not only the smoke from manufactories which produced the evil, but the smoke from the chimneys of private dwellings. Feeling a very deep interest in this matter, he could speak at length in supporting this resolution, but he would follow the advice of the promoters of this movement, and consume his own smoke.

Mr. ERNEST HART said there remained one yet agreeable duty to perform, a slight omission which he wished to rectify, which should have been mentioned in connection with the awards of the Manchester Exhibition—that in two classes awards were made, in respect to which the London Committee had not been able to present medals. These were in respect to Messrs. Stott and Co., for their Gas Regulator, and to Messrs. Kershaw & Co., for their non-conducting composition. These medals had not been awarded, not because they did not deserve medals, but because it had been previously arranged at the London Exhibition (and the Manchester Committee had graciously consented to that arrangement) that they should make no awards in respect to accessory appliances. In proposing a vote of thanks to the Chairman, Mr. Hart said he felt sure they could not separate without expressing their deep obligations to the noble Duke, and a mere vote of thanks would not express their sentiments. He knew, and they all knew, in this movement, as in so many public movements which tended to promote the happiness and elevate the moral and physical being of his fellow-creatures, the Duke of Westminster had been a most influential leader. They were grateful for the kindness of the Duke in favouring them with his presence, in giving them so much of his time as he had given them, and he was sure that that consideration would aid, if anything could aid, to that sincerity with which they would join in this vote of thanks.

Mr. WM. HAUGHTON (Royal Horticultural Society), in seconding the vote of thanks, said he felt he could not add words to the eloquent and graceful words which had fallen from his friend Mr. Ernest Hart, and he would only add that it was impossible for them to overrate the value of the cordial assistance, the kindness, and the personal services which the noble Duke had rendered to the battle which they were waging.

The CHAIRMAN said he was extremely obliged to them for their very cordial reception. He begged to thank them very much for coming there; it was an occasion of great interest, and he felt highly honoured in being able to welcome so many eminent men and women under his roof. He hoped the meeting would be a benefit, and that the institution would continue and prosper.

Thanks by acclamation to Lady Grosvenor for her kindness in presenting the medals were enthusiastically accorded.

NATIONAL SMOKE ABATEMENT INSTITUTION.

In accordance with the foregoing resolution, the National Smoke Abatement Institution has been duly incorporated by authority of the Board of Trade.

The chief objects of the proposed Association are :—

(*a*) To promote the abatement of coal smoke and other noxious products of combustion in cities and other places, in order to render the atmosphere as pure and as pervious to sunlight as practicable.

(*b*) To check the present serious waste of coal, and the direct and indirect loss and damage accompanying the over-production of smoke and noxious products of combustion.

The objects of the Association will be carried out by the following among other means, viz. :—

1. By promoting and encouraging the better and more economical use of coal and coal products, the selection of suitable fuel, and the general improvement in producing, applying, and using heat and light for domestic and industrial purposes.

2. By conducting tests of smoke-preventing apparatus and fuels in manufacturing towns as well as in London.

3. By reporting on tests, granting awards for approved fuels, methods, or apparatus; by lectures, printing, publishing, and circulating statistics and other information for the guidance of local authorities, inventors, manufacturers, and others ; and by giving instruction to workmen, servants and others in the use of new appliances, &c.

A printed copy of the Memorandum of Association will be forwarded on application.

The *Terms of Membership* are one guinea per annum, or such larger sum as members may voluntarily choose to contribute. No liability will be incurred by becoming a member beyond a guarantee of one guinea, payable, if required, in the event of the termination of the Association ; and any member can withdraw from the Association by giving notice of wish to do so. Members will be entitled to copies of such publications as the Committee may decide to distribute from time to time post free. The Committee invite the co-operation, assistance, and suggestions of those who can, by their scientific influence or their commercial relations, advance the object. The Committee hope the Institution will be well supported by all classes.

OFFICES: 44 BERNERS STREET, LONDON, W

INDEX.

THE ANTHRACITE COAL COMPANY,
LIMITED.

Head Office: GARFIELD BUILDINGS, 150 HOLBORN, E.C.

ANTHRACITE SMOKELESS COAL.

ANALYSIS 'BIG VEIN,'

GWAUN-CAE-GURWEN COLLIERY, GARNANT.

Moisture	None
Volatile Matter	9·40
Non-Volatile Matter, or Coke.	90·60
	100·00
Carbon	92·27
Hydrogen	3·58
Oxygen / Nitrogen	1·80
Sulphur...	0·68
Ash	1·67
	100·00

PURE ANTHRACITE FROM GWAUN CAE GURWEN AND YSTRADGUNLAIS COLLIERIES

The WHOLE of the Anthracite Coal used for the Smoke Abatement Trials and Tests was supplied by the ANTHRACITE COAL COMPANY, Limited.

EXTRACTS FROM THE SMOKE ABATEMENT COMMITTEE'S REPORT

As to Anthracite Coal for Domestic Purposes,

PAGE 94 OF REPORT SAYS :—

'Anthracite as a fuel appears, from the general results of testing, to be as efficient as Wallsend Coal in open grates, whilst it is decidedly more efficient in close stoves. It is also remarkably more efficient in grates and stoves in which a supply of warmed fresh air is provided and delivered into the room. Such a function does not appear to be fulfilled economically with Wallsend Coal as fuel.'

And as to Anthracite Coal for Steam Boiler Furnaces,

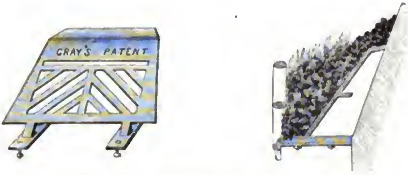
PAGE 136 SAYS :—

'The Anthracites of the Anthracite Coal Company were, in general, rough of fracture and friable. The most efficient of them for the ratio of the evaporated water to the fuel, according to column 16 of the Table, was No. 7, *the "Brass Vein" Anthracite, from Ystradgunlais, by which 14·23 lbs. of water was evaporated per lb. of fuel from and at 212° F.* At the end of the eight hours' trial, there was but little clinker and ash, and the clinker did not adhere to the fire-bars. *This Anthracite proved, in fact, to be one of the best of all the samples that were tested in combining evaporative efficiency with maintenance of pressure and ease of stoking.*'

This proves that Anthracite Coal takes a high position as a fuel for all purposes, independent of the great advantages of its entire freedom from smoke, and its economy in use and price.

All Orders for the **Anthracite Smokeless Coal** should be sent to the above address, where it can be had of proper quality, and delivered in sizes suitable for every purpose, and where it can be seen in use in improved types of Kitcheners, Sitting-room Grates, Stoves, Steam Boiler Furnace, and Smith's Forge.

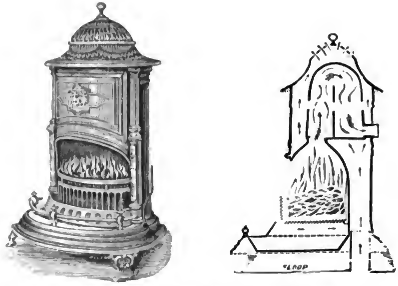
OPEN GRATES.



J. G. GRAY.—PERFORATED RACK FOR OPEN GRATES.

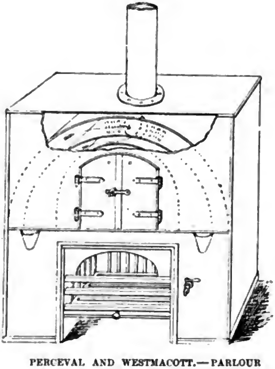
THE BRITISH SANITARY COMPANY.—CARRICK'S VENTILATING GRATE.

Plate 2.—*OPEN GRATES.*



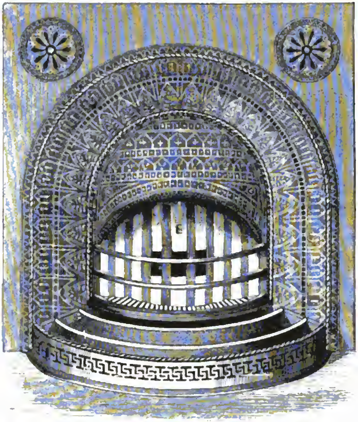
JOHN WRIGHT AND CO.—HYGIENIC VENTILATING STOVE.

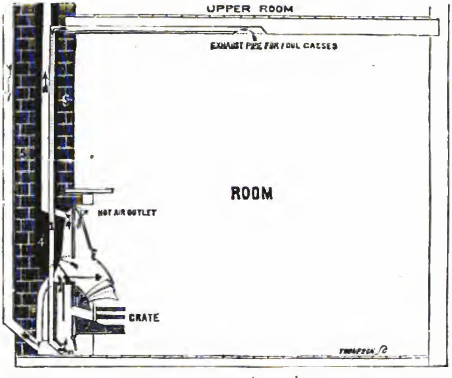
THOMAS POTTER AND SONS.—THERMHYDRIC VENTILATING HOT-WATER GRATE.



PERCEVAL AND WESTMACOTT.—PARLOUR STOVE, HEATING AND COOKING.

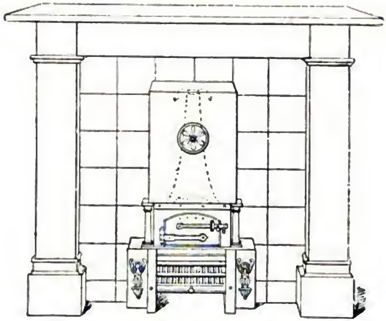
PLATE 3.—*OPEN GRATES.*





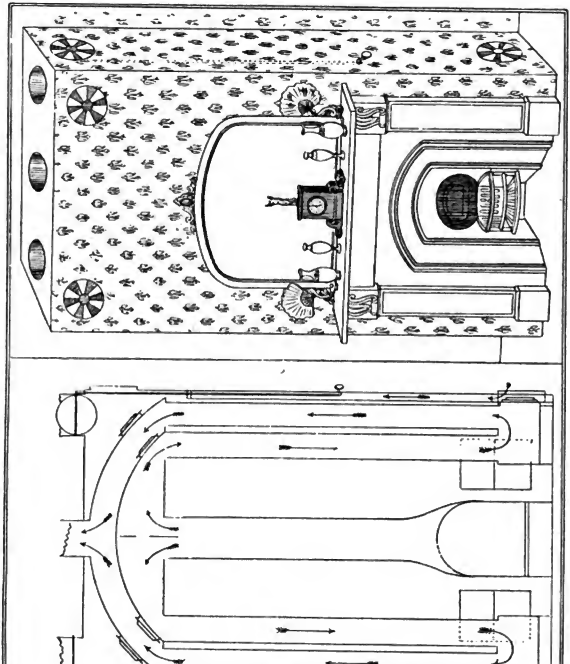
A. B. VERRIER.—THE 'COMET' GRATE.

WILLIAM POORE AND CO.—'TRIUMPH' STOVE.



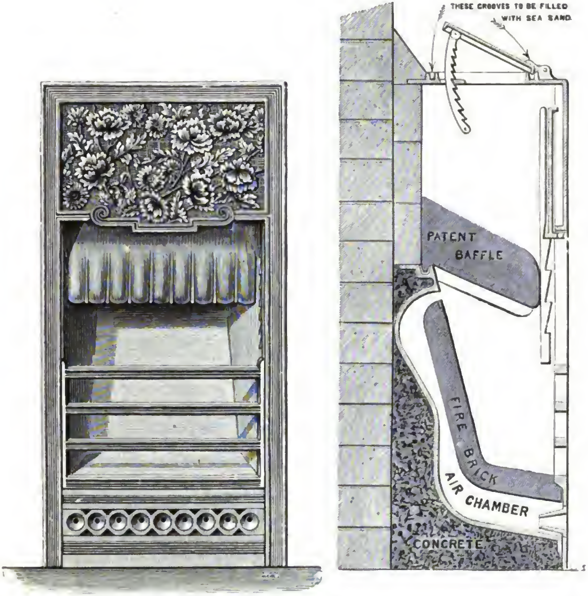
PERCEVAL AND WESTMACOTT.—'SANITARY' STOVE.

PLATE 5.—*OPEN GRATES.*



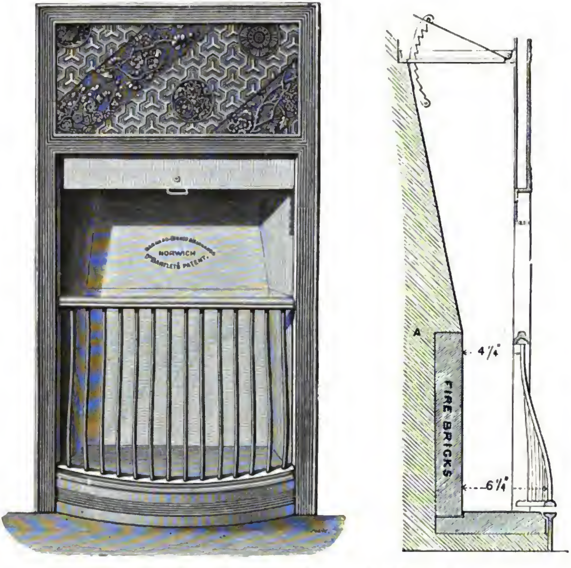
GEORGE HALLER AND CO.— KOHLHOFER'S HOT-AIR STOVE.

THE WAVISH PATENT FUEL ECONOMISER COMPANY.—'ECONOMISER' FOR OPEN GRATES.

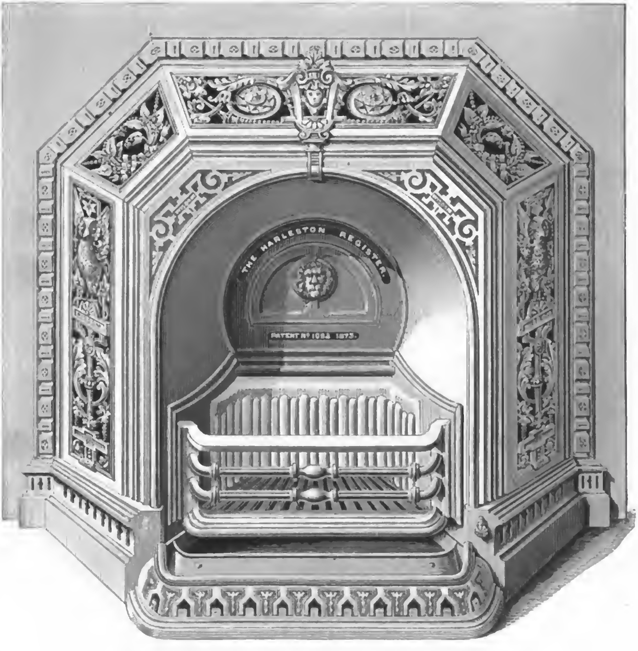


BARNARD, BISHOP, AND BARNARDS.—'GLOW-FIRE.'

PLATE 7.—*OPEN GRATES.*

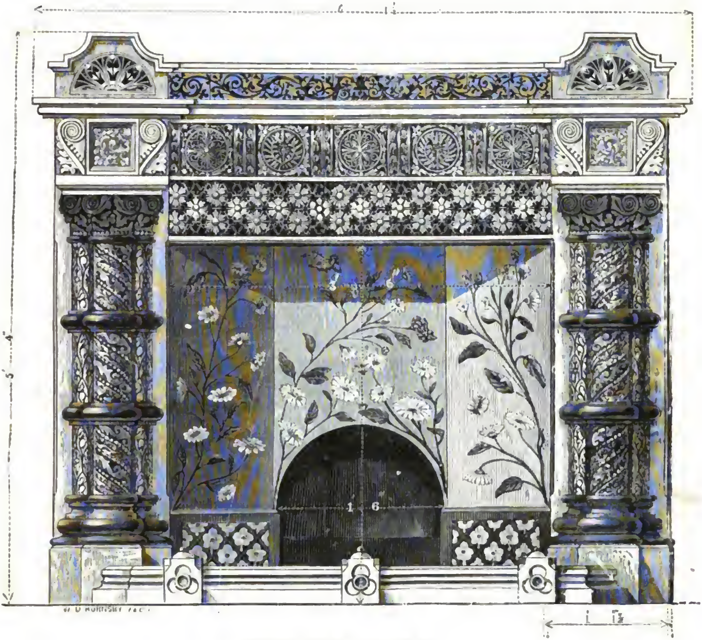


BARNARD, BISHOP, AND BARNARDS.—THE 'BARTLET' GRATE.



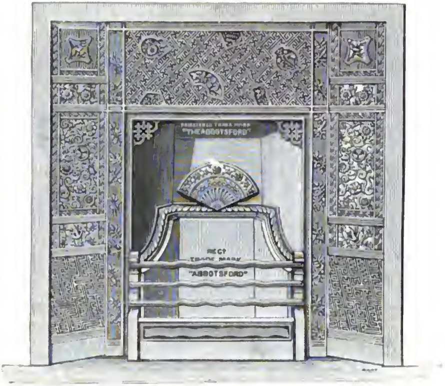
MARSHALL, WATSON, AND MOORWOOD.—THE 'HARLESTON' GRATE.

PLATE 9.—*OPEN GRATES.*

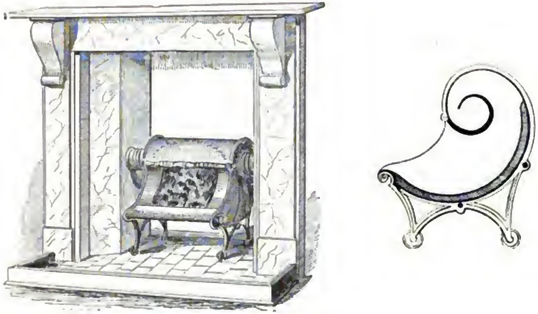


DOULTON AND CO.—TILE GRATE.

PLATE 10.—*OPEN GRATES.*

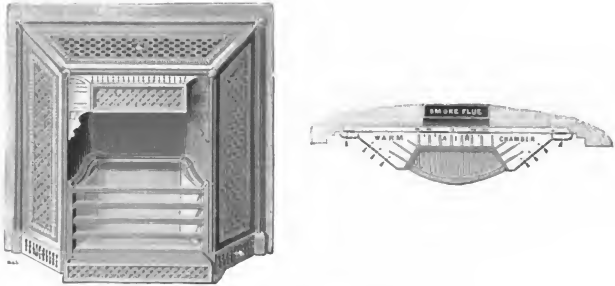


THE DERWENT FOUNDRY COMPANY.—THE 'ABBOTSFORD' GRATE.

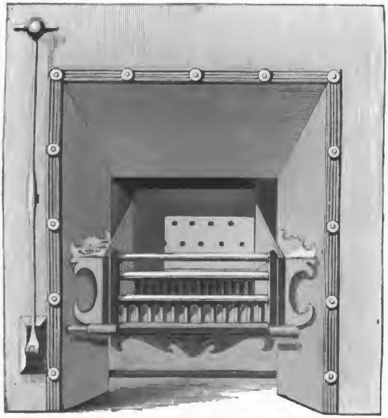


J. B. PETTER.—'NAUTILUS' STOVE.

PLATE 11.—*OPEN GRATES.*

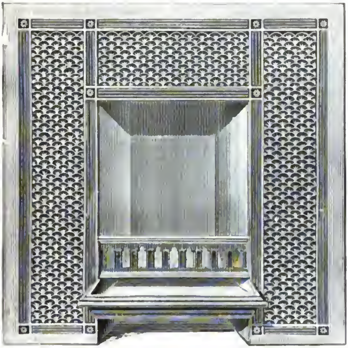


STEEL AND GARLAND.—'WHARNCLIFFE' GRATE.

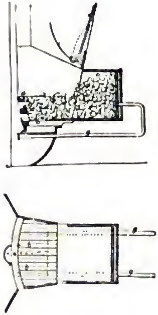


E. R. HOLLANDS.—UNDER FED GRATE.

PLATE 12.—*OPEN GRATES.*

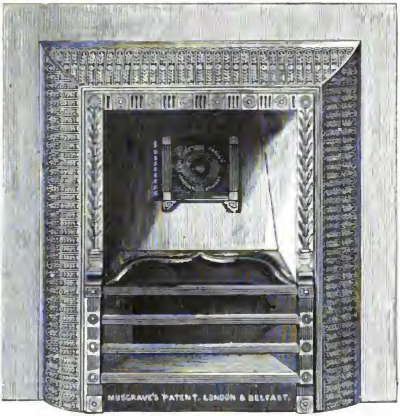


BROWN AND GREEN.—UNDER-FED GRATE.

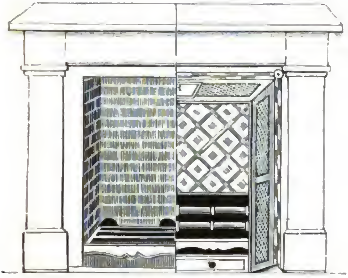


A. C. ENGERT.—FIRE-GRATE, WITH COKING-BOX AT THE BACK.

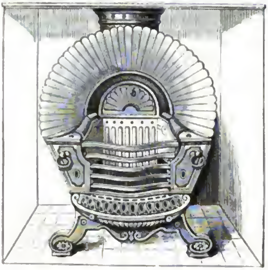
Plate 13.—*OPEN GRATES.*



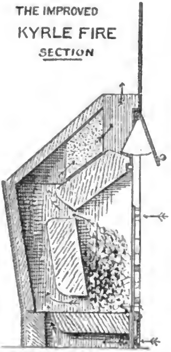
MUSGRAVE AND CO.—'ULSTER' GRATE.



JOHN M. STANLEY.—HOPPER-FED GRATE



HENRY E. HOOLE.—RADIATING AND REFLECTING GRATE.

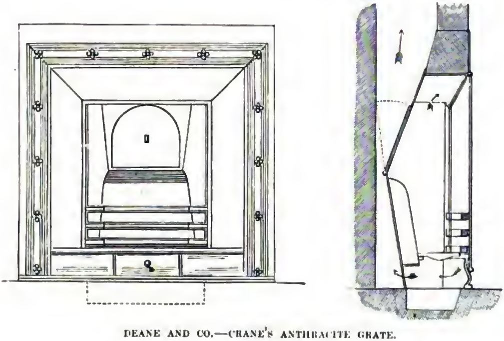


THE IMPROVED
KYRLE FIRE

THE COALBROOKDALE COMPANY.—THE 'KYRLE' GRATE.

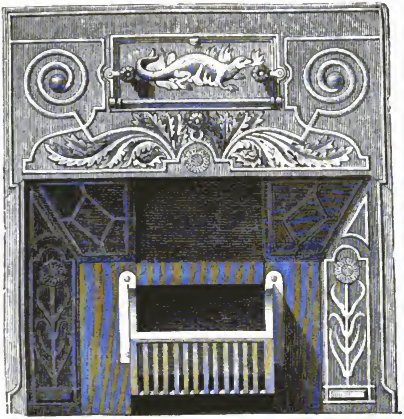
PLATE 15.—*OPEN GRATES.*

ARCHIBALD SMITH AND STEVENS.—'WONDERFUL' GRATE.

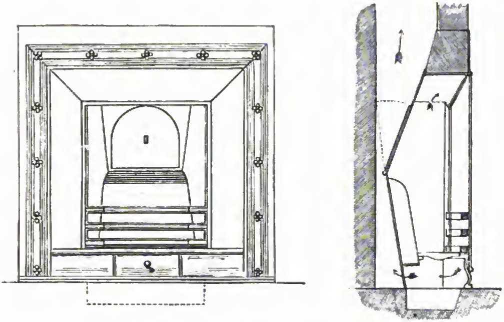


DEANE AND CO.—CRANE'S ANTHRACITE GRATE.

PLATE 15.—*OPEN GRATES.*

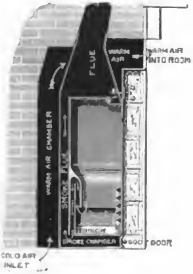


ARCHIBALD SMITH AND STEVENS.—'WONDERFUL' GRATE.

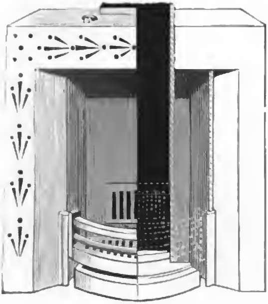


DEANE AND CO.—CRANE'S ANTHRACITE GRATE.

PLATE 16.—*OPEN GRATES.*

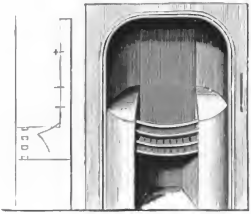


STEEL AND GARLAND. 'KENSINGTON' GRATE.



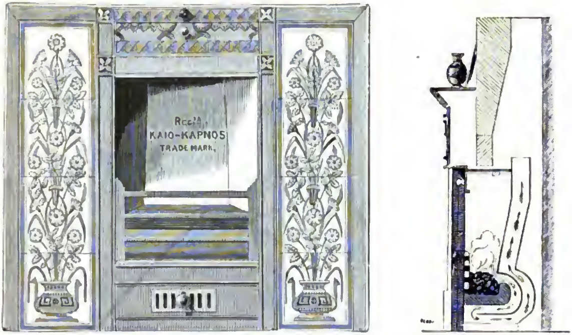
JOSEPH MOORE. OPEN GRATE.

T. E. PARKER.
THE 'VENCEDOR' GRATE.

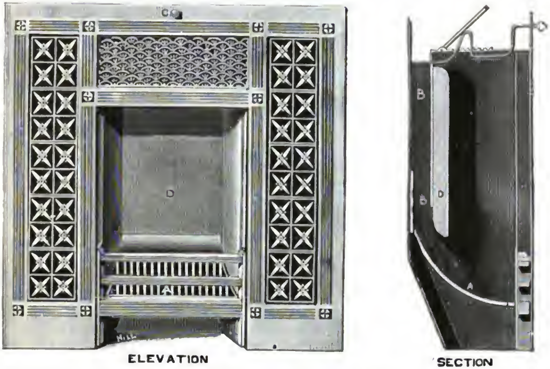


W. I. HENRY.
'SMOKE PURIFYER' HOB GRATE ('CALPEAN').

Plate 17.—*Open Grates.*



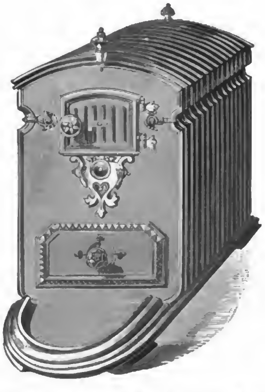
CLARK, BUNNETT, AND CO.—INGRAM'S 'KAIO-KAPNOS' GRATE.



ELEVATION SECTION

BROWN AND GREEN.—'LUTON' REGISTER GRATE.

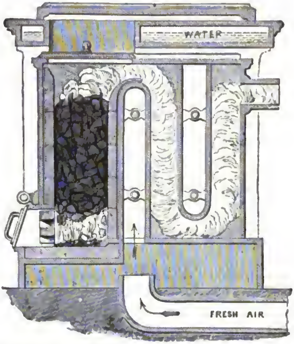
CLOSE STOVES.



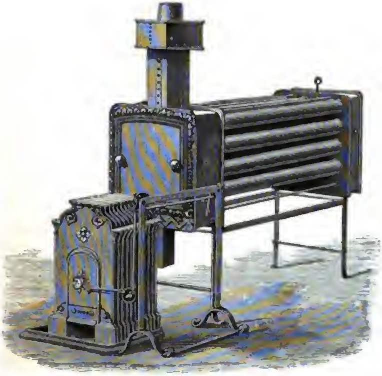
THE DERWENT FOUNDRY COMPANY.—JOBSON'S 'SLOW-COMBUSTION GILL-STOVE.'

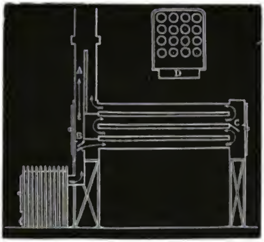
C. B. GREGORY.—SMOKE-BURNING FURNACE.

PLATE 20.—*CLOSE STOVES.*

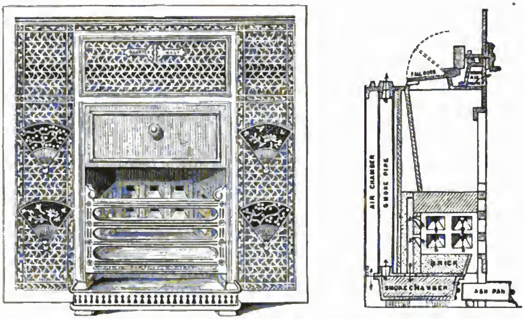


MUSGRAVE AND CO.—SLOW-COMBUSTION STOVE.





REV. HENRY J. NEWCOME.—TUBULAR AIR-WARMER.



OPEN GRATE.

YATES, HAYWOOD, AND CO.—REDMAYNE'S GRATE.

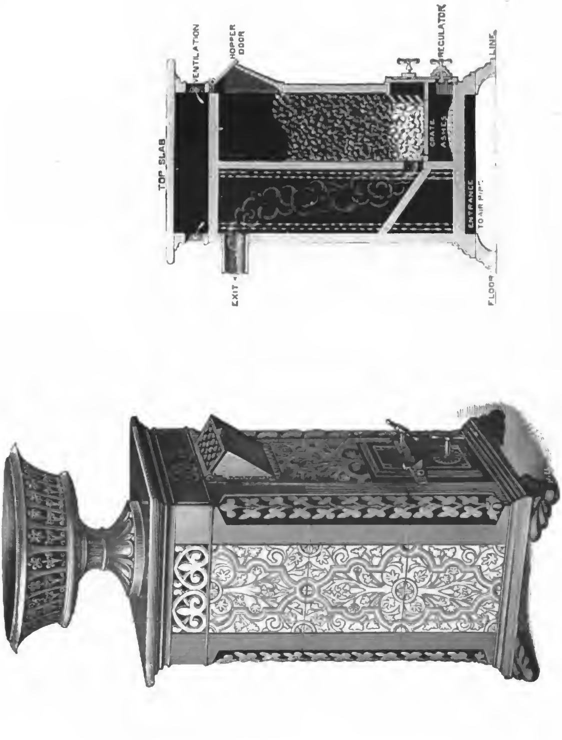
YATES, HAYWOOD AND CO.,
THE 'MISER' STOVE.

PLATE 22.—*CLOSE STOVES.*

CHARLES PORTWAY AND SON.
'TORTOISE' SLOW-COMBUSTION HEATING-STOVES.

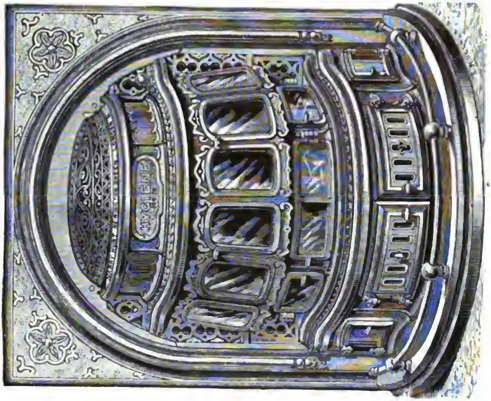
WILLIAM STOBBS.—'CRYSTAL' VENTILATING-GRATE.

PLATE 23.—*CLOSE STOVES.*

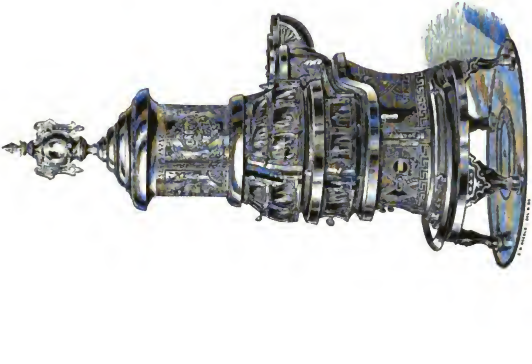


DOULTON AND CO.—TOP-FEEDING STOVE.

PLATE 24.—*CLOSE STOVES.*



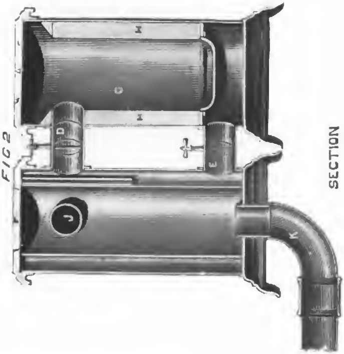
HARRY HUNT.—'HYGIESE' VENTILATING-STOVE.



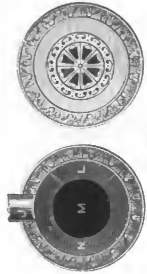
HARRY HUNT —THE 'CROWN JEWEL' STOVE.

PLATE 25.—*CLOSE STOVES.*

FIG 2



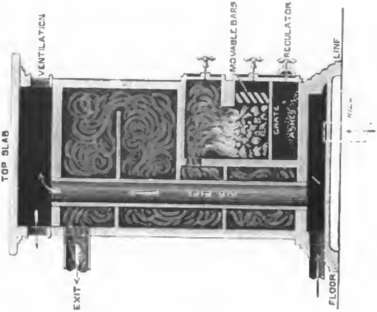
SECTION



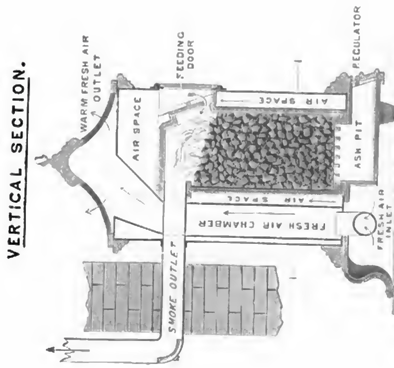
PLAN

BROWN AND GREEN.—'TWIN' STOVE.

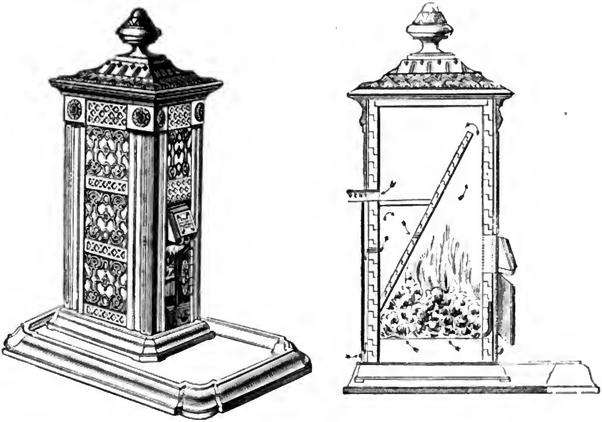
PLATE 26.—*CLOSE STOVES.*



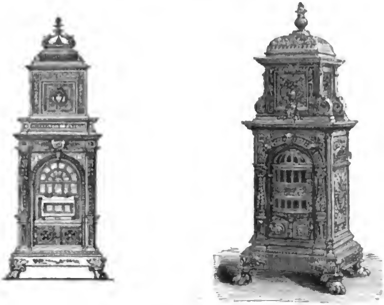
DOULTON AND CO.— ORDINARY LARGE STOVE, WITH BAFFLES.



J. F. FALWIG AND CO.—'CALORIGEN' AIR-WARMING STOVE.

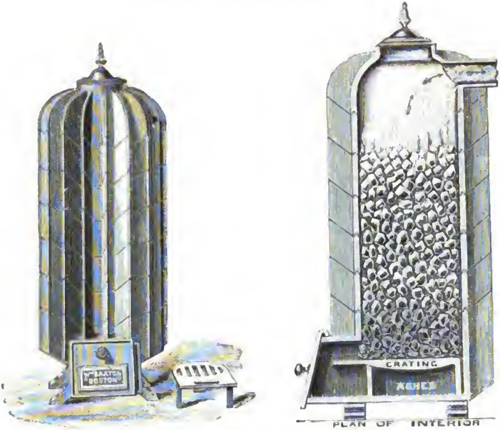


JAMES DUNNACHIE.—'STAR' HEATING-STOVE.



FRANZ LÖNHOLDT.—ANTHRACITE STOVES.

Plate 28.—*CLOSE STOVES.*

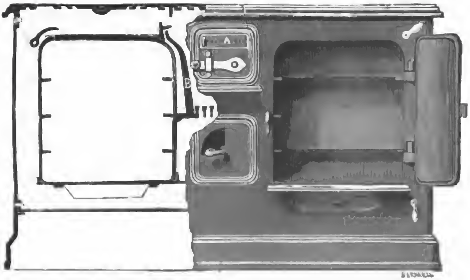


W. BARTON.—'PREMIER' STOVE.

R. W. CROSTHWAITE.—ARMSTEAD-GREGORY STOVE.

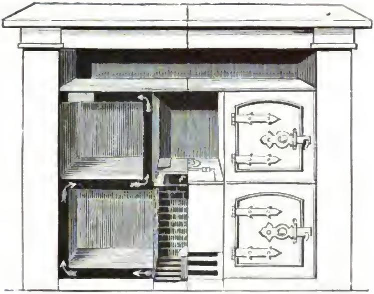
BROWN AND GREEN.—'ALBION' STOVE.

COAL KITCHENERS.

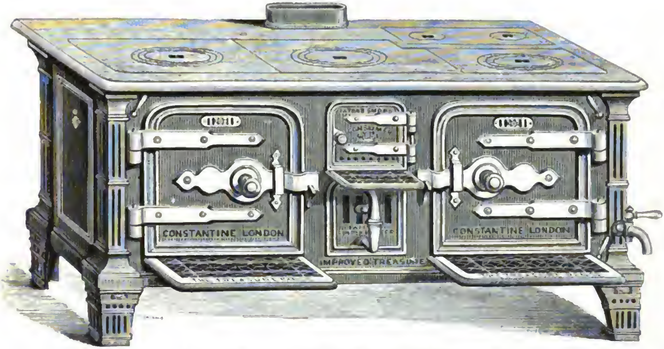


THE WILSON ENGINEERING COMPANY.—THE WILSON PORTABLE KITCHEN RANGE.

PLATE 30.—*COAL KITCHENERS.*

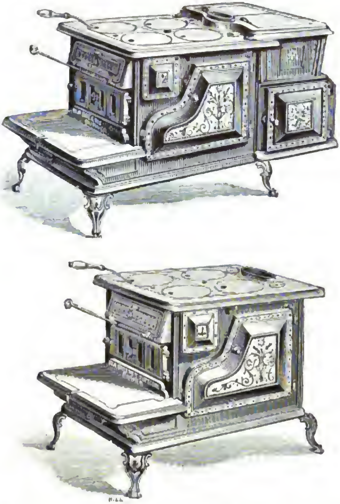


JOHN M. STANLEY.—HOPPER-FED COOKING-RANGE.



T. J. CONSTANTINE.—THE 'TREASURE' COOKING-RANGE.

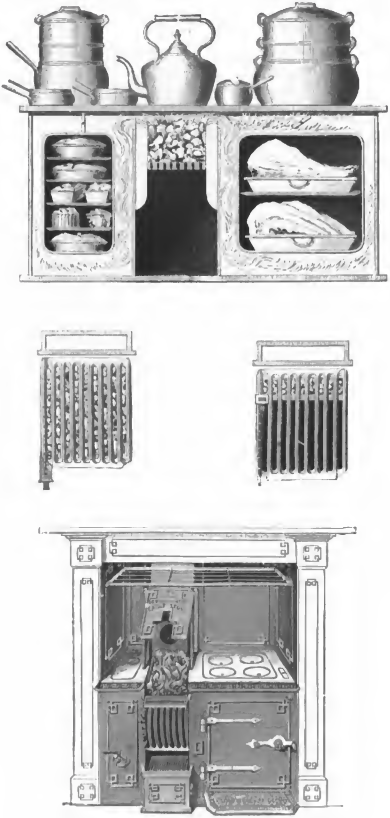
Plate 31.—*COAL KITCHENERS.*



CHARLES CHURCHILL AND CO.—THE 'GREENE' SOFT-COAL COOKING-STOVE.

NEWTON, CHAMBERS, AND CO.—THE 'THORNCLIFFE' COOKING-RANGE.

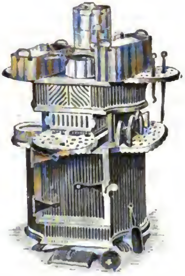
Plate 32.—*Coal Kitcheners.*



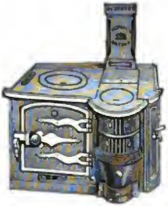
THE EAGLE RANGE COMPANY.—'EAGLE' RANGES.

PLATE 33.—*COAL KITCHENERS.*

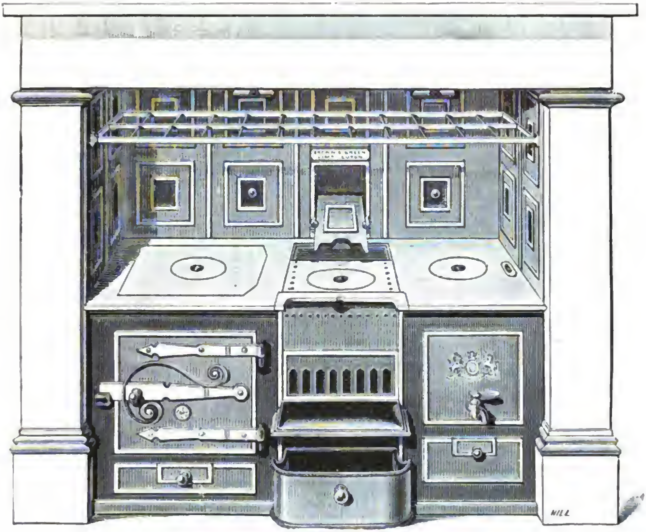
WILLIAM STOBBS.—'BEEBE' KITCHEN RANGE.

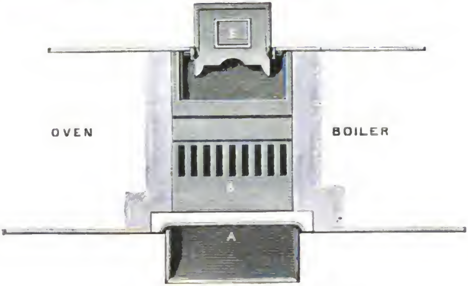


THE SUNLIGHT STOVE CO.
DUTCH OVEN.



THE RADIATOR RANGE COMPANY.—'RADIATOR' RANGES.

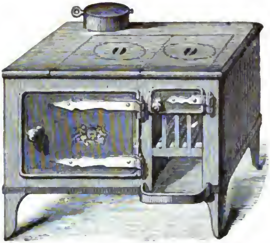




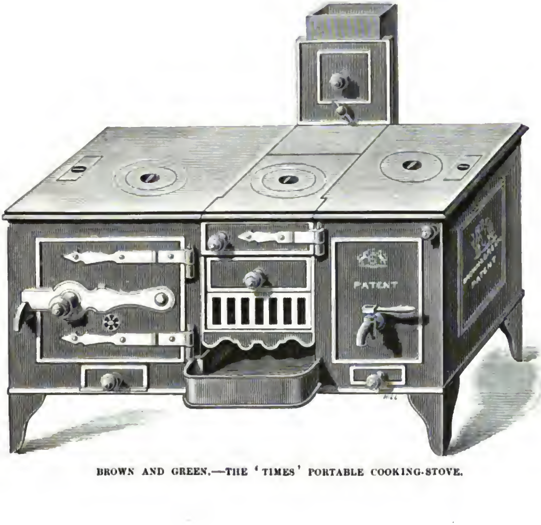
PLAN

BROWN AND GREEN.—UNDER-FED KITCHENER.

PLATE 35.—*COAL KITCHENERS.*

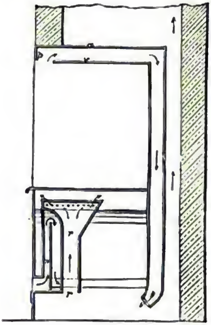


BROWN AND GREEN.—THE 'GEM' COOKING-STOVE.



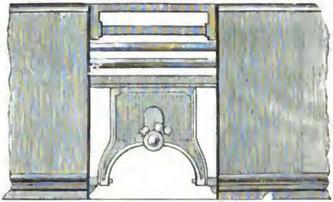
BROWN AND GREEN.—THE 'TIMES' PORTABLE COOKING-STOVE.

PLATE 36.—*COAL KITCHENERS.*



J. COURT.—VENTILATING KITCHENER.

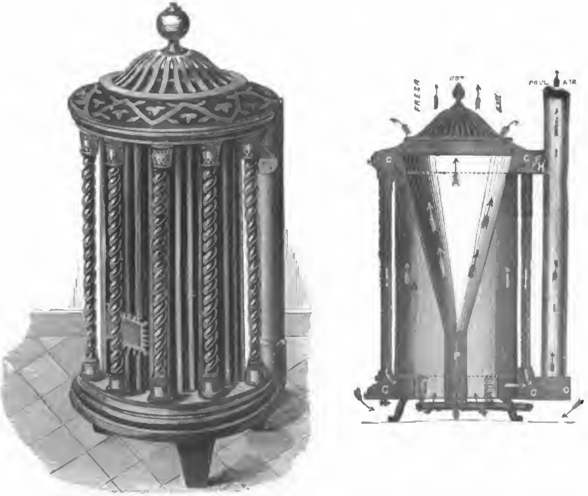
THE FALKIRK IRON COMPANY.—THE 'FALKIRK' SMOKELESS CLOSE-FIRE KITCHENER.



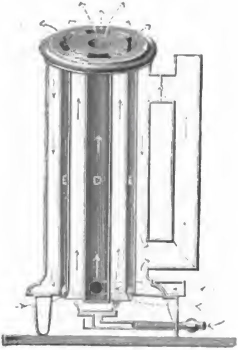
J. AND J. M'MILLAN.—UNDER-GRATE FUEL-FEEDING APPARATUS.

Plate 37.

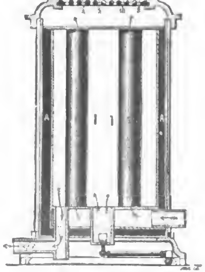
GAS HEATING-APPARATUS.



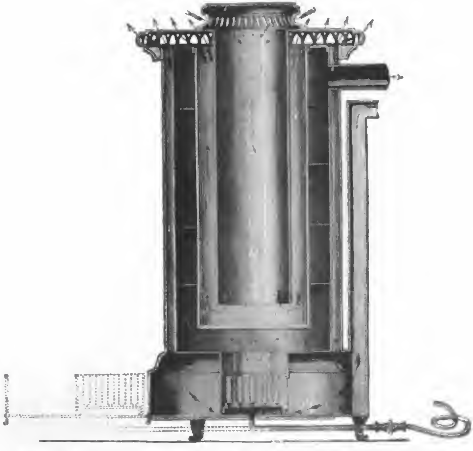
THE SANITARY AND ECONOMIC SUPPLY ASSOCIATION.—DR. BOND'S 'EUTHERMIC' VENTILATING GAS HEATING-STOVE. (PATTERN A.)



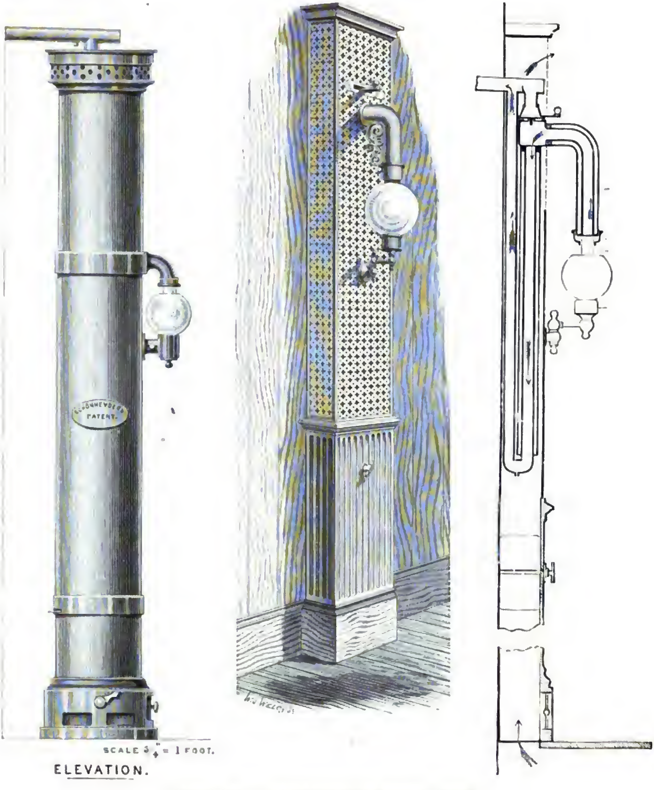
SANITARY AND ECONOMIC SUPPLY ASSOCIATION. — DR. BOND'S 'EUTHERMIC' VENTILATING GAS STOVE. (PATTERN B.)



J. C. STARK AND CO.
COX'S VENTILATING GAS HEATING-STOVE.

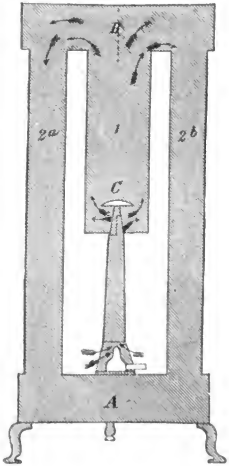


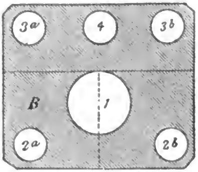
WM. HARVIE AND CO.—DR. ADAMS' VENTILATING GAS HEATING-STOVE.



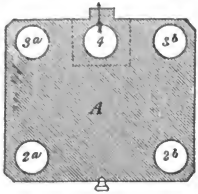
STRODE AND CO.—SCHÖNHEYDER'S SANITARY STOVES.

PLATE 40.—*GAS HEATING-APPARATUS.*





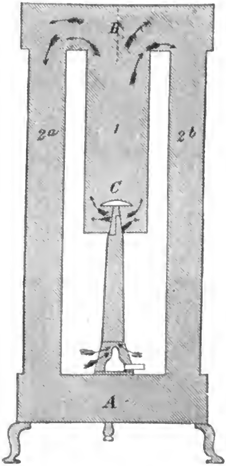
UPPER BOX.

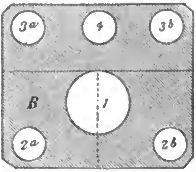


LOWER BOX.

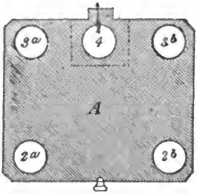
GEORGE HALLER AND CO.—KOHLHOFER'S HOT-AIR GAS STOVE.

PLATE 40.—*GAS HEATING-APPARATUS.*





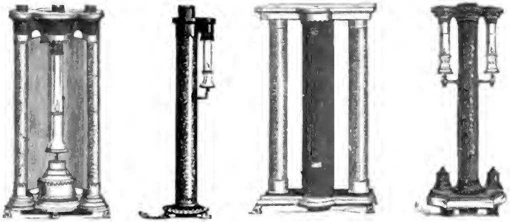
UPPER BOX.



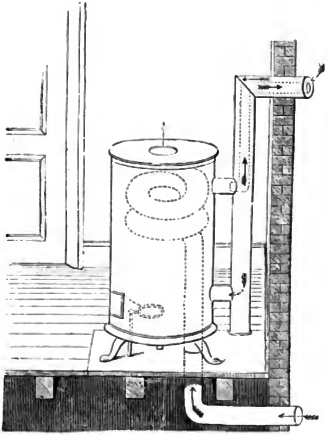
LOWER BOX.

GEORGE HALLER AND CO.—KOHLHOFER'S HOT-AIR GAS STOVE.

PLATE 41.—*GAS HEATING-APPARATUS.*

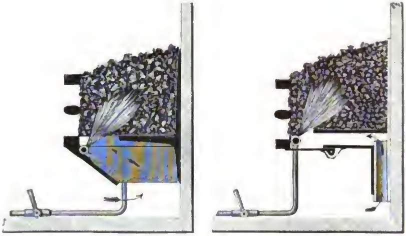


RITCHIE AND CO.—'LUX CALOR' VENTILATING-STOVES.

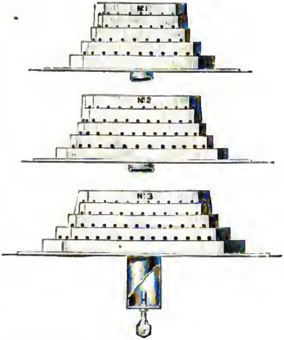


J. F. FARWIG AND CO.—GEORGE'S GAS 'CALORIGEN.'

PLATE 42.—*GAS HEATING-APPARATUS.*



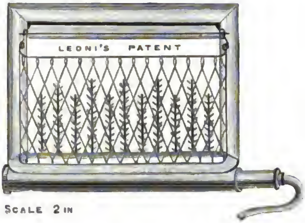
WADDELL AND MAIN.—DR. SIEMENS' GAS-AND-COKE FIRE-GRATE.



WADDELL AND MAIN.—HISLOP'S METALLIC GAS FIRE.

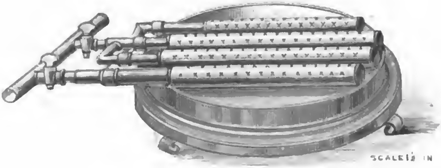
CHARLES WILSON.—NEW 'CARLTON' GAS HEATING-STOVE.

CHARLES WILSON.—THE 'CARLTON' GAS FIRE.



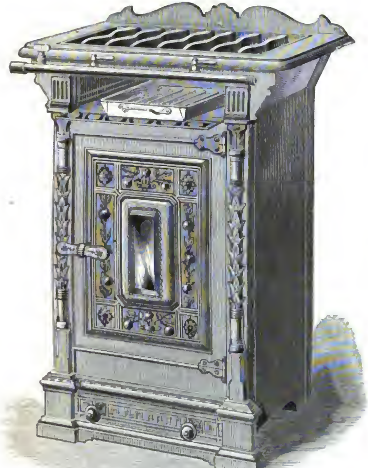
S. LEONI AND CO.—GAS FIRE.

PLATE 44.—*GAS HEATING-APPARATUS.*



S. LEONI AND CO.—INSTANTANEOUS WATER-HEATER.

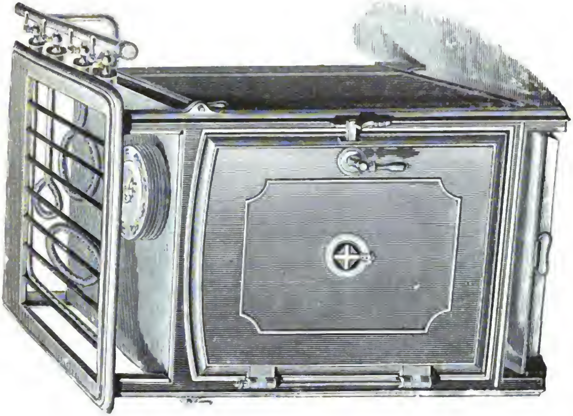
GAS COOKING-APPARATUS.



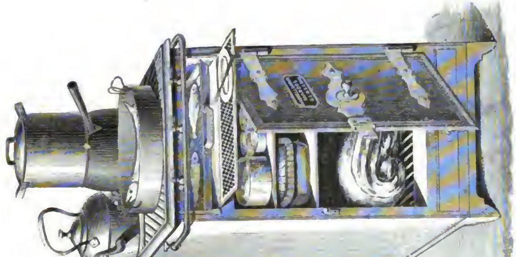
CHARLES WILSON.—GAS COOKING-STOVE.

J. C. STARK AND CO.—GAS COOKING-STOV

PLATE 46.—*GAS COOKING-APPARATUS.*



H AND C. DAVIS AND CO.—GAS COOKING-STOVE.

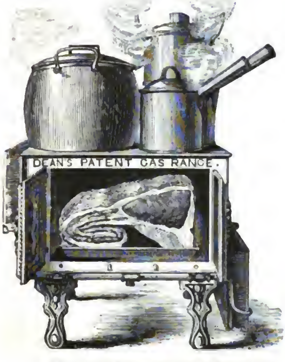


WADDELL AND MAIN.—THE 'UNIVERSAL DOMESTIC' GAS COOKING-STOVE.

P P

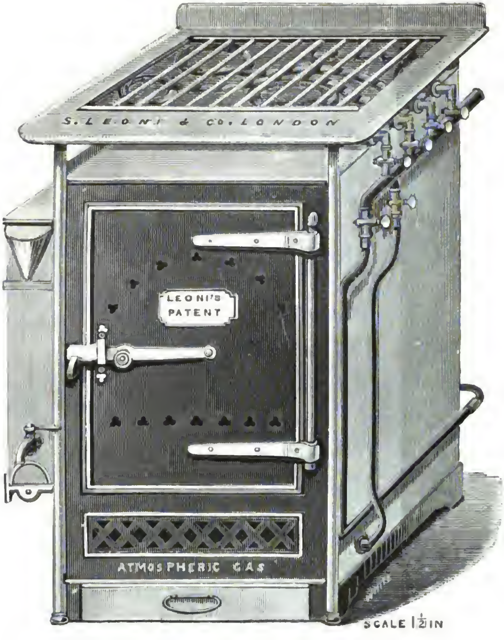
PLATE 47.—*GAS COOKING-APPARATUS.*

G. J. COX.—'REGENERATOR' GAS COOKING-STOVE.



J. DEAN AND SON.—GAS COOKING-STOVE.

JOHN WRIGHT AND CO.—GAS COOKING-STOVE.



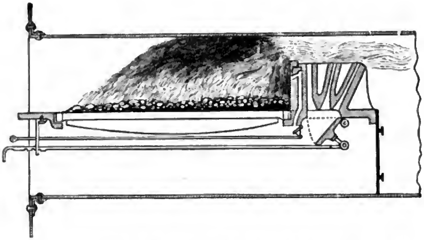
S. LEONI AND CO.—GAS KITCHENER.

PLATE 49.—*GAS COOKING-APPARATUS.*

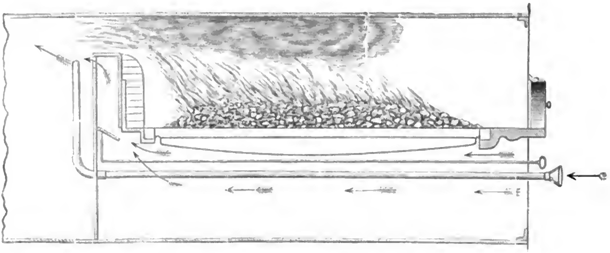
J. SLATER AND CO.—LARGE GAS COOKING-OVEN.

Q Q

STEAM-BOILER APPLIANCES.

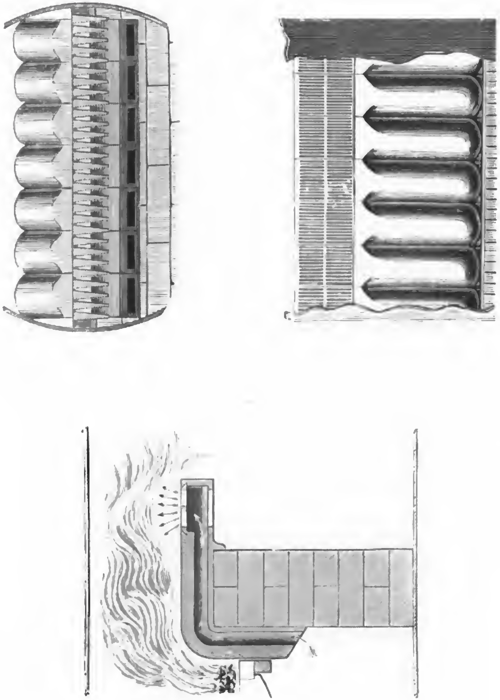


CHUBB AND CO.—ATMOSPHERIC-BLAST SMOKE-PREVENTING BRIDGE.



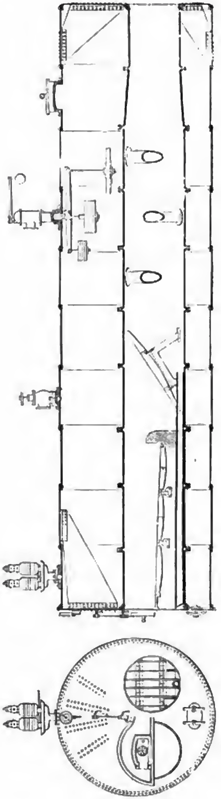
E. L. GOWTHORPE.—SMOKE-CONSUMING BRIDGE FOR STEAM-BOILERS.

PLATE 51.—*STEAM-BOILER APPLIANCES.*



IRELAND AND LOWNDS.—SMOKE-PREVENTING AIR TUBES.

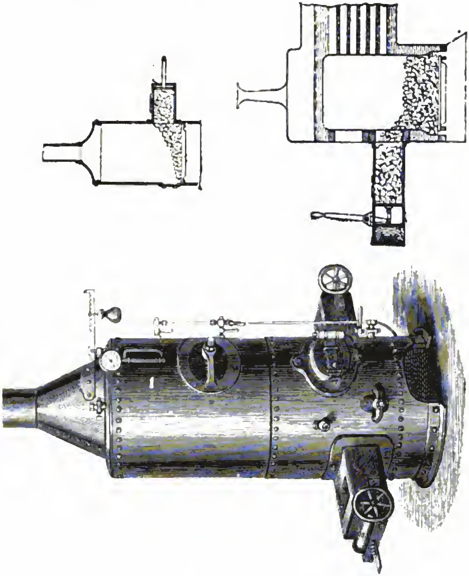
PLATE 52.—*STEAM-BOILER APPLIANCES.*



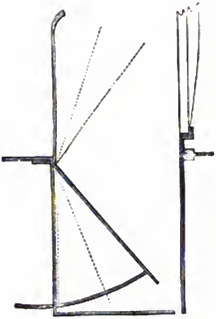
DUNCAN BROTHERS.—W. S. WELTON'S FUEL-ECONOMISER (INCLINED GRID).

W. A. MARTIN AND CO.—SMOKE-PREVENTING FURNACE-DOOR AND GRATE.

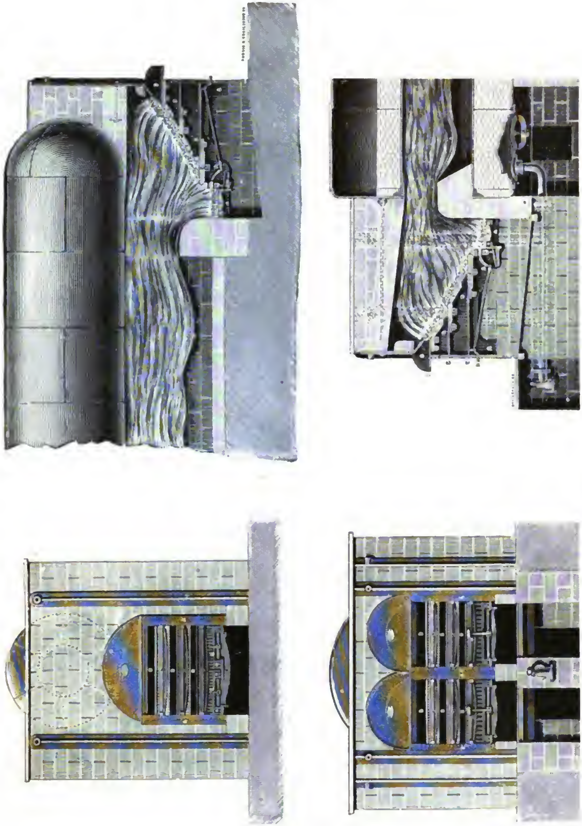
PLATE 53.—*STEAM-BOILER APPLIANCES.*



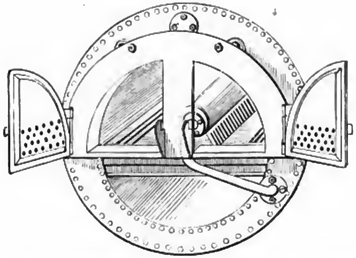
A. C. ENGERT.—FUEL-FEEDING COKING-BOXES.



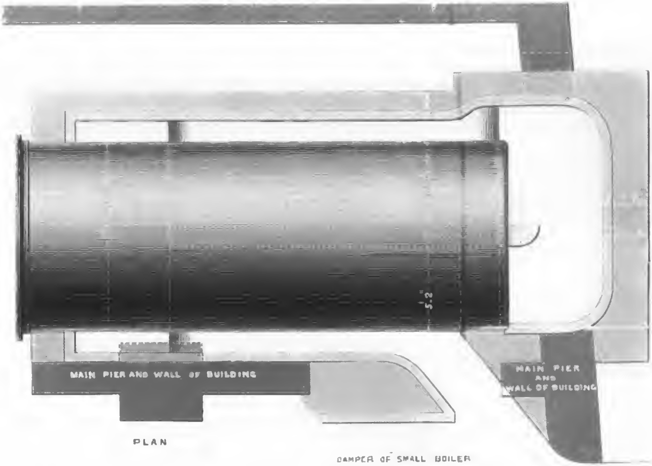
A. C. ENGERT.—SMOKE-PREVENTING APPARATUS.



JAMES FARRAR AND CO.—BARBER'S SMOKELESS FURNACE.

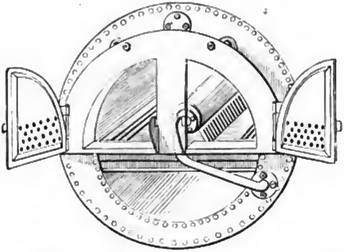


THE WAVISH PATENT FUEL-ECONOMISER COMPANY.—WAVISH'S ECONOMISER AND SMOKE CONSUMER, WITH WATER CIRCULATOR.

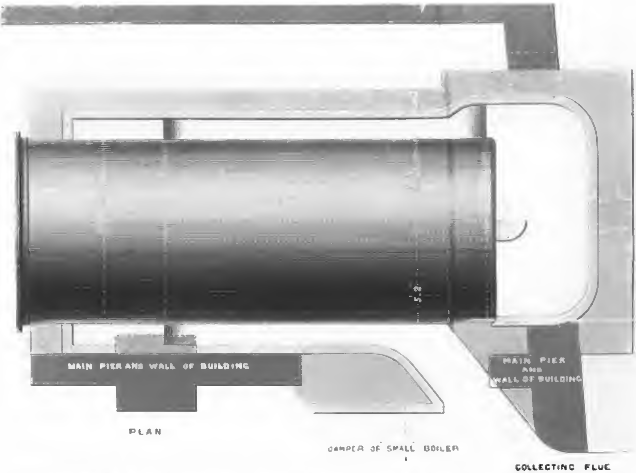


LIVET'S PATENT IMPROVED BOILERS AND FURNACE COMPANY.—STEAM-BOILER AT THE PRINTING WORKS OF MESSRS. CLAY, SONS, AND TAYLOR, QUEEN VICTORIA STREET (EMPLOYED AS A TESTING BOILER FOR FUELS).

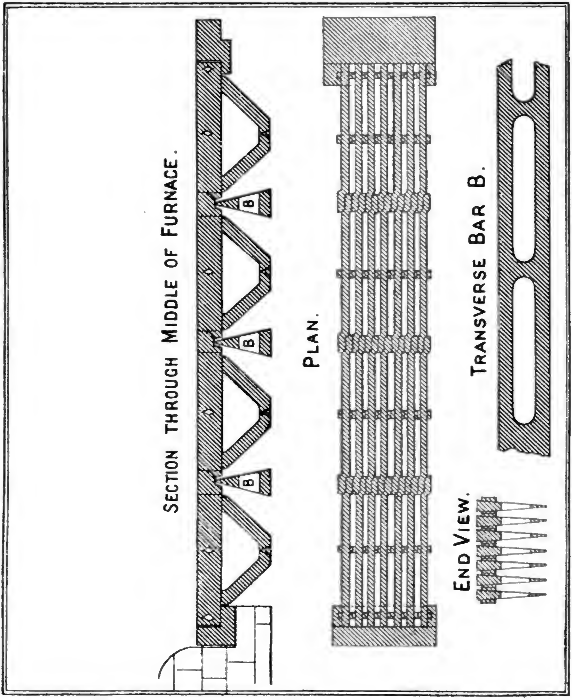
PLATE 55.—*STEAM-BOILER APPLIANCES.*



THE WAVISH PATENT FUEL-ECONOMISER COMPANY.—WAVISH'S ECONOMISER AND SMOKE CONSUMER, WITH WATER CIRCULATOR.

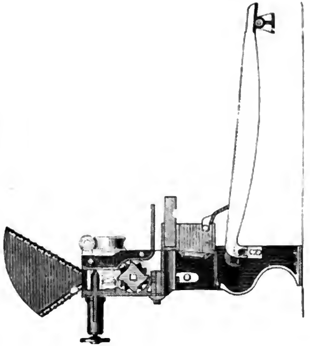


LIVET'S PATENT IMPROVED BOILERS AND FURNACE COMPANY.—STEAM-BOILER AT THE PRINTING WORKS OF MESSRS. CLAY, SONS, AND TAYLOR, QUEEN VICTORIA STREET (EMPLOYED AS A TESTING BOILER FOR FUELS).

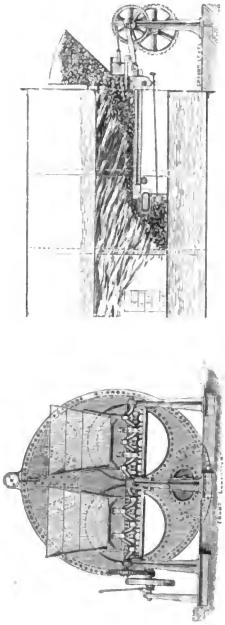


GEORGE HALLER AND CO.—KOHLHOFER'S FIRE-BARS.

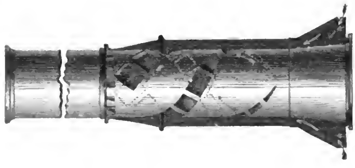
PLATE 58.—*STEAM-BOILER APPLIANCES.*



THE PATENT STEAM-BOILER COMPANY.—KNAP'S MECHANICAL STOKER.

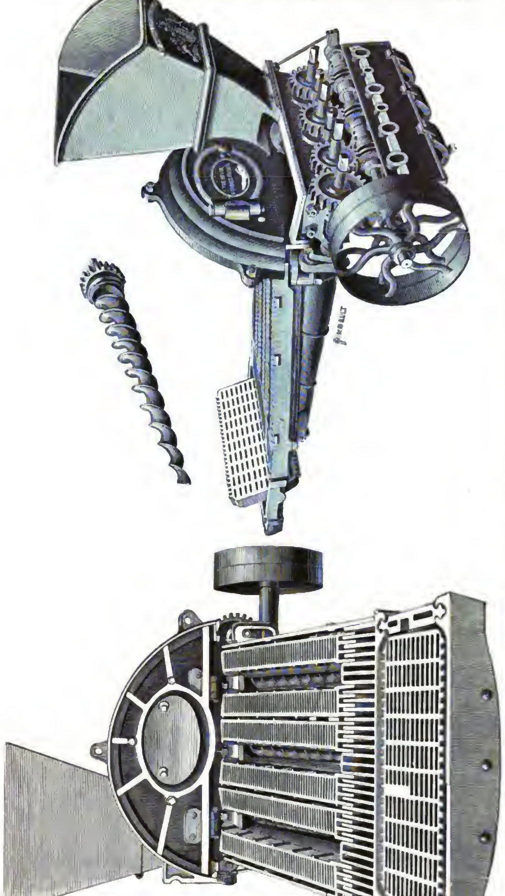


GEORGE SINCLAIR.—MECHANICAL STOKER.



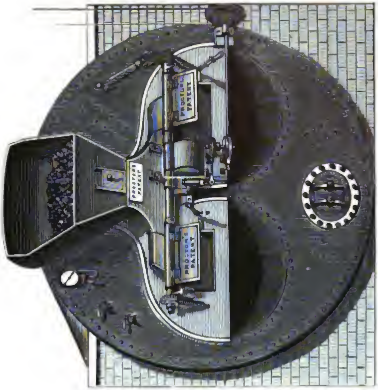
E. G. WÉRY.—ATMOSPHERIC SMOKE-CONSUMING CHIMNEY.

PLATE 59.—*STEAM-BOILER APPLIANCES.*

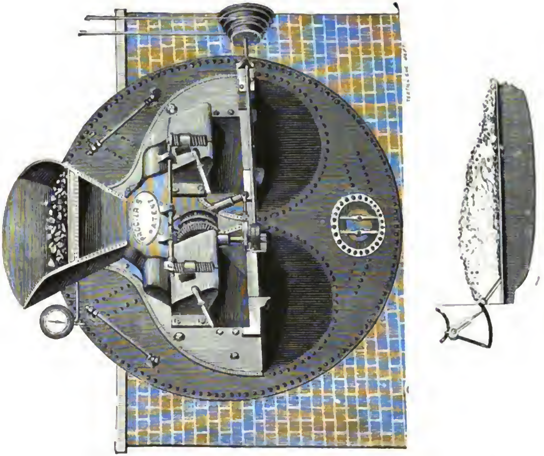


KNOWLES AND HALSTEAD.—HOLROYD-SMITH'S MECHANICAL STOKER.

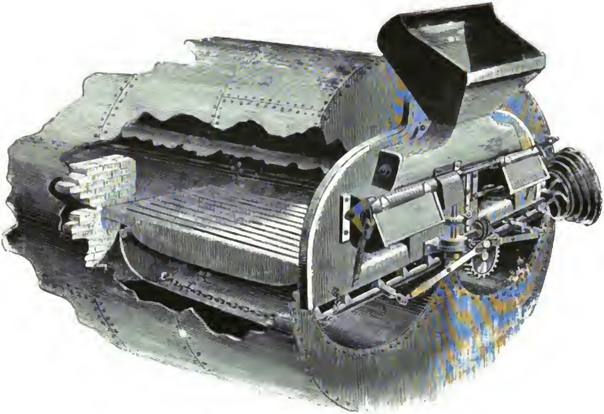
PLATE 60.—*STEAM-BOILER APPLIANCES.*



JAMES PROCTOR.—IMPROVED MECHANICAL STOKER.

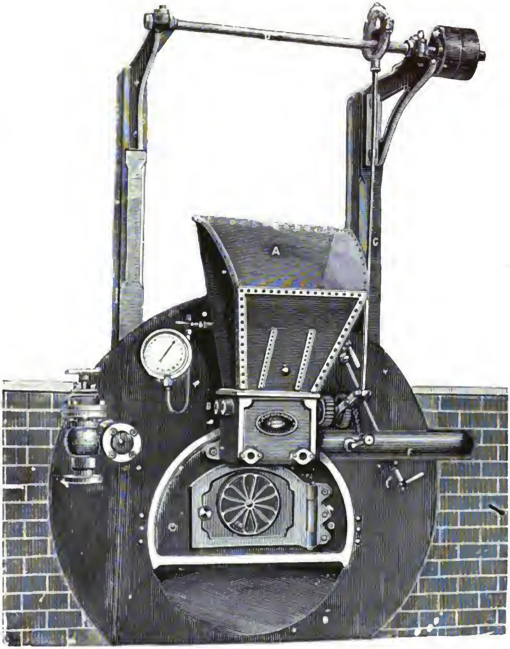


JAMES PROCTOR.—MECHANICAL STOKER.



JAMES PROCTOR.—MECHANICAL STOKER (IMPROVED).

JAMES PROCTOR.—MECHANICAL STOKER (IMPROVED).

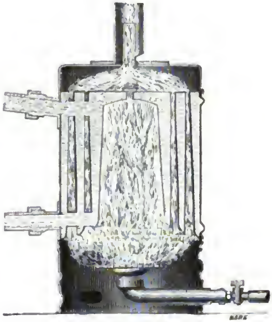


JAMES NEWTON AND SON.—MECHANICAL STOKER.

HEATING-APPARATUS.

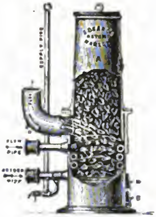
W. AND S. DEARDS.—COIL BOILER, IN BRICKWORK.

COKE BOILER.

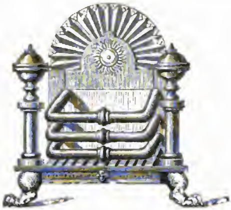


GAS BOILER.

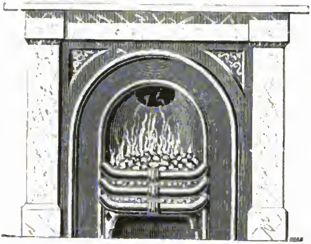
FRANKLIN, HOCKING, AND CO.



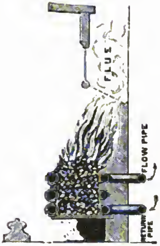
PORTABLE COIL STOVE.



COIL DOG-GRATE.

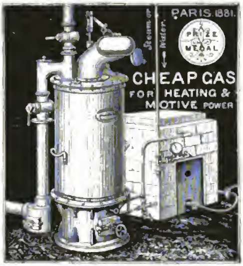


COIL GRATE.

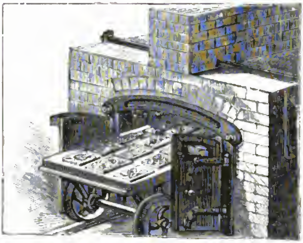


COIL GRATE.

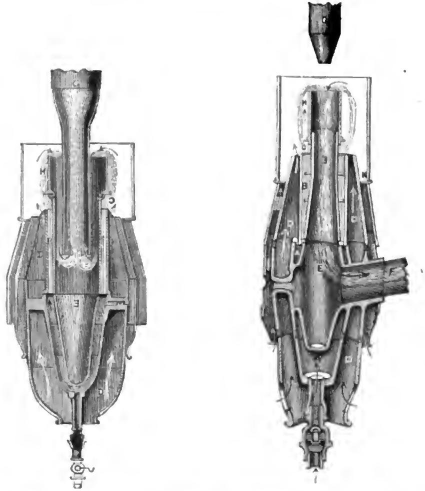
W. AND S. DEARDS.



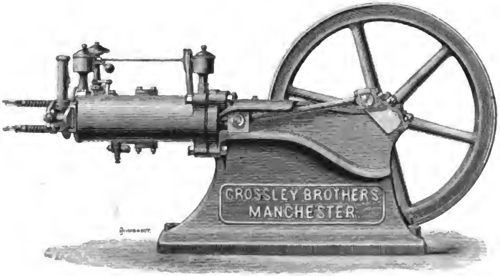
THE DOWSON ECONOMIC GAS COMPANY.
CHEAP-GAS PRODUCER.



THOMPSON BROTHERS.—GAS KILN.



SIEMENS PATENT GAS LIGHT COMPANY.—'REGENERATOR' GAS LAMPS.

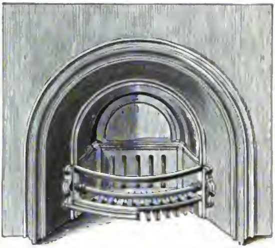


CROSSLEY BROTHERS.—'OTTO' SILENT GAS ENGINE.

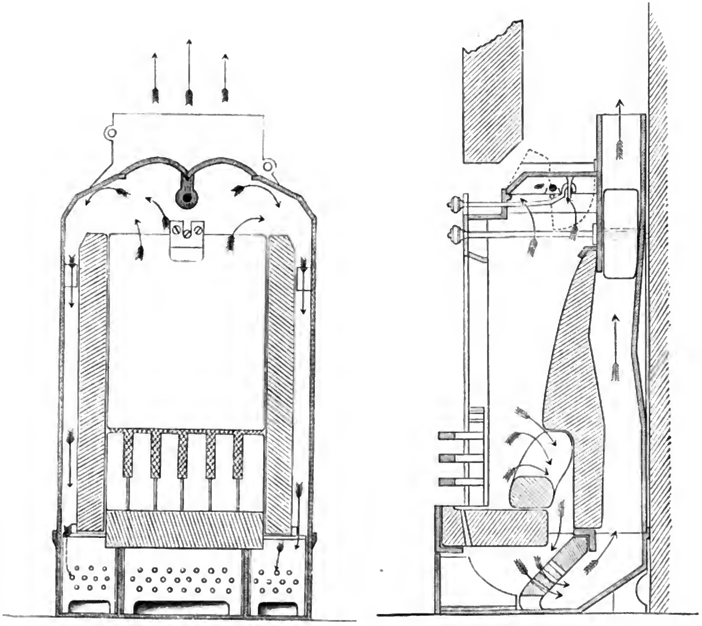
MANCHESTER EXHIBITION.

HYDES AND WIGFULL.—'TORTOISE' LAUNDRY-STOVE.

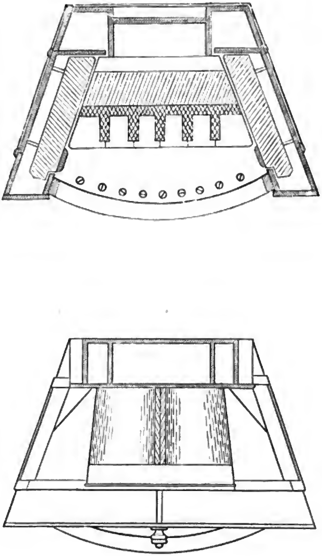
E. H. SHORLAND.—THE 'MANCHESTER' STOVE.



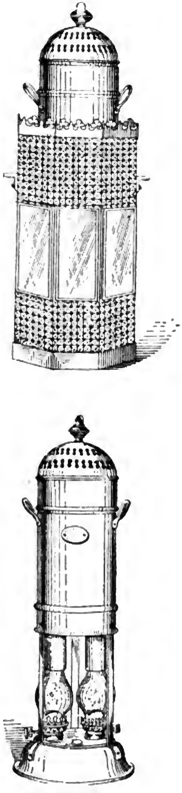
THE FALKIRK IRON COMPANY.
GAS-AND-COKE FIRE.



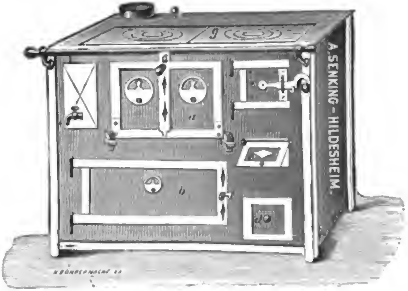
JAFFREY AND CO.—SMOKE-CONSUMING GRATE.



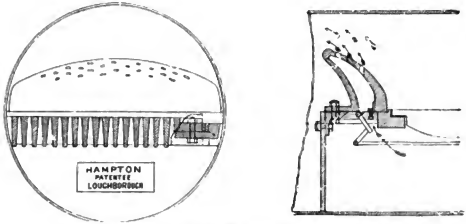
JAFFREY AND CO.—SMOKE-CONSUMING GRATE.



W. THORNBURN,
PETROLEUM HEATING-STOVES

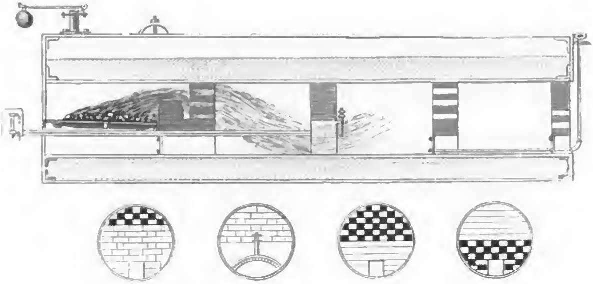


ELLIOTT, ALSTON, AND OLNEY.—SENKING'S COOKING-STOVE.

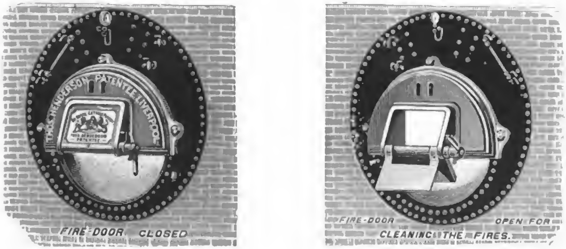


J. HAMPTON.—FIRE-PROOF SMOKE-CONSUMING BRIDGE.

PLATE 71.—*MANCHESTER EXHIBITION.*

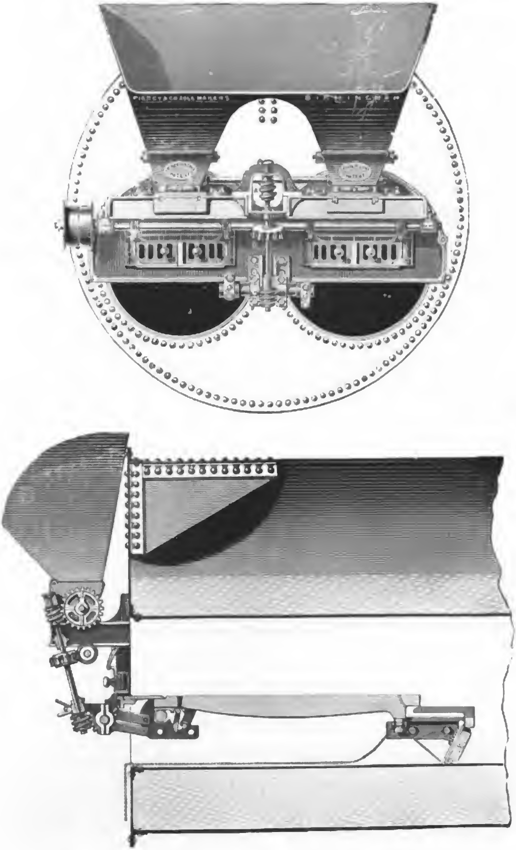


JAMES MOORE.—NUTT'S SMOKE-CONSUMING FURNACE.



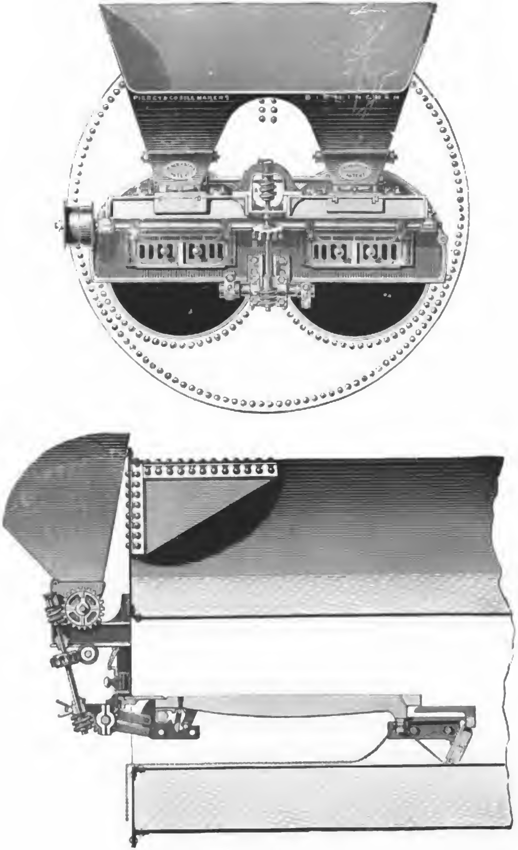
THOMAS HENDERSON.—FURNACE-[illegible] AND FIRE-DOOR.

PLATE 72.—*MANCHESTER EXHIBITION.*

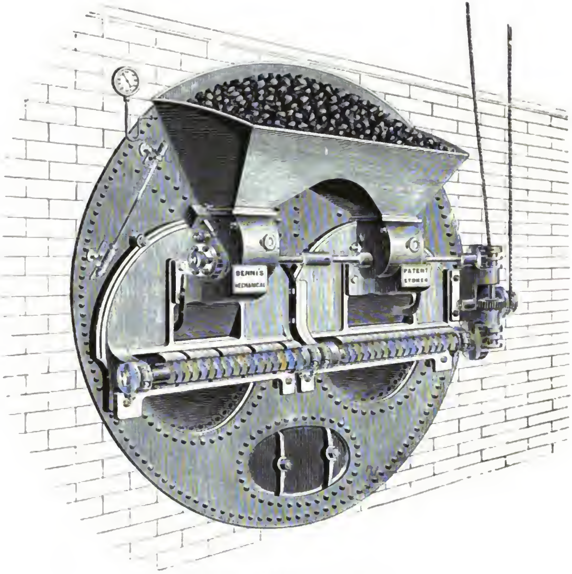


THOMAS HENDERSON.—MECHANICAL STOKER.

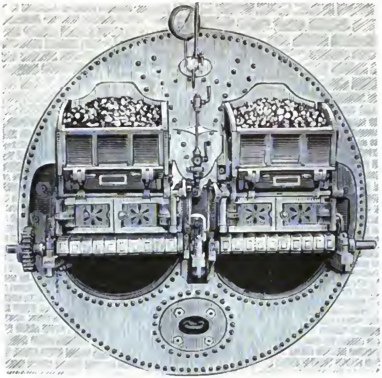
Plate 72.—*Manchester Exhibition.*

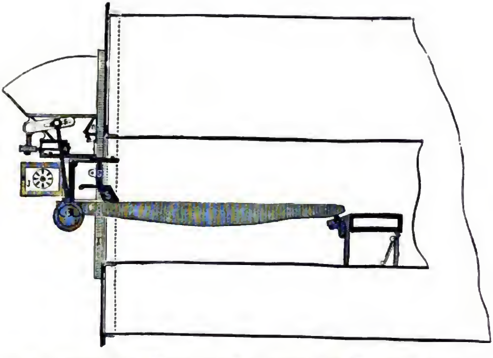


THOMAS HENDERSON.—MECHANICAL STOKER.



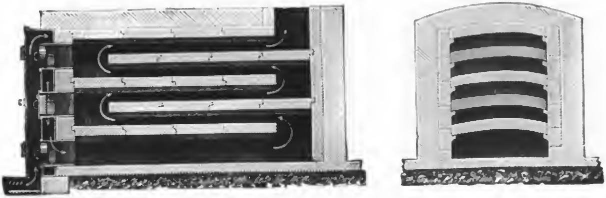
E. BENNIS.—MECHANICAL STOKER.



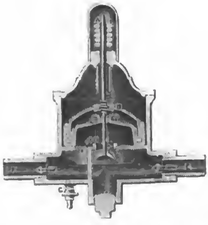


THE CHADDERTON IRONWORKS COMPANY.—M'DOUGALL'S MECHANICAL STOKER.

Plate 75.—*MANCHESTER EXHIBITION.*



MICHEL PERRET.—MULTIPLE-STAGED FURNACE.



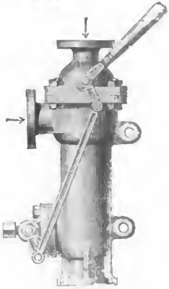
JAMES STOTT AND CO.—SELF-ACTING GAS-VALVE.

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

ZZ 3

KÖRTING'S

PATENT UNIVERSAL



INJECTOR

FOR FEEDING BOILERS

Works equally well non-lifting or lifting.

Can be made to lift 24 feet.

Works with High or Low steam pressure.

Works with Hot or Cold Water.

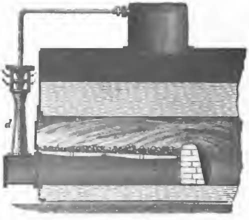
Forces the water into the Boiler considerably above boiling point, thereby increasing the durability of the Boiler.

IS STARTED BY SIMPLY TURNING **ONE** LEVER.

KÖRTING'S PATENT

STEAM-JET UNDERGRATE BLOWERS

Decrease smoke,
Cure bad draught,
Cause great saving in fuel,
Prevent the firebars from burning,
and are used with equally good results for Boilers, Gas Producers, and Heating Furnaces in Iron, Steel, Chemical, and Glass Works.



FOR PARTICULARS APPLY TO

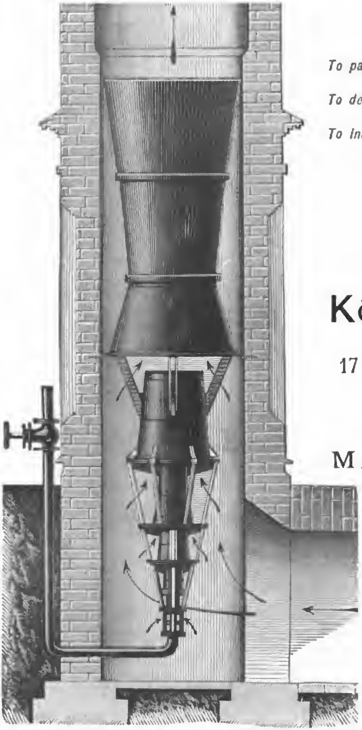
KÖRTING BROTHERS,

17 LANCASTER AVENUE, FENNEL STREET,

MANCHESTER.

0

KÖRTING'S PATENT
STEAM-JET CHIMNEY VENTILATOR



Is used with advantage—

To partially prevent smoke;

To develop greater intensity of heat;

To increase the evaporating power of Land and Marine Boilers.

FOR PARTICULARS APPLY TO

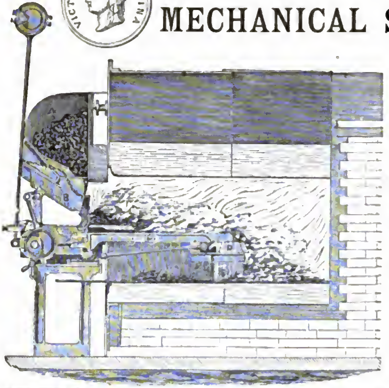
KÖRTING BROS.,

17 LANCASTER AVENUE,

FENNEL STREET,

MANCHESTER.

VICARS' PATENT IMPROVED
MECHANICAL STOKER.



By applying this Stoker to Steam Boilers as much duty can be obtained from FINE SLACK as from an equal quantity of LARGE COAL of the same quality, thereby effecting a *considerable saving*. It is the most perfectly Smokeless Stoker known; to a very great extent it supersedes the labour of stoking, and its management is very simple; the various parts of the Stoker are not subject to much wear and tear, the bars being well protected from the destructive action of the fire.

Recent improvements made in the above Stoker enable the fireman when getting up steam, before the Engine can be started, to fire it by hand as easily as an ordinary furnace, and new bars can be put in without stopping the Boiler.

In addition to the Stoker being applicable to Steam Boilers, it can be adapted to Evaporating, Brewing Pans, &c.

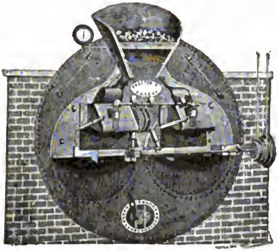
For Prices and Particulars apply to

T. & T. VICARS,
Engineers,
LIVERPOOL.

AWARDED PRIZE MEDAL AT THE SMOKE ABATEMENT EXHIBITION, SOUTH KENSINGTON, LONDON, 1882

This Machine evaporated 9.4 lbs. of water per lb. of coal—water at 110° with a very common slack, from Hindley Field Coal Co., Wigan, the price being 3/3 per ton at the Colliery.

[The test was made by Mr. Longridge, Chief Engineer of the Engine and Boiler Insurance Company (Limited), Manchester, at the mill of Mr. Eli Heyworth, Blackburn, on the four days, Nov. 25th to 28th, 1881.



PROCTOR'S
NEW PATENT
MECHANICAL STOKER AND MOVABLE FIRE BARS.

Upwards of 800 Boilers have been supplied with these Stokers.

J. PROCTOR, PATENTEE AND MAKER.
Tuesdays and Fridays: MANCHESTER EXCHANGE, Pillar No. 6.
HAMMERTON STREET IRON WORKS, BURNLEY.

PATRONISED BY THE PRINCESS LOUISE.

By Royal Letters Patent.

SMOKE ABATEMENT EXHIBITION.

THE ADJUSTABLE BACK FOR FIRE GRATES. MORE HEAT. CONSIDERABLE LESS COAL. LESS SMOKE

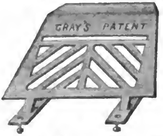
Testimonials from various parts of the United Kingdom.

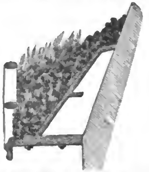
IMPORTANT INVENTION FOR PREVENTING WASTE IN THE CONSUMPTION OF COALS.

If you want the heat from the fire to come into the room instead of going up the chimney try one of

GRAY'S ADJUSTABLE BACKS FOR FIRE GRATES.

71 MILTON STREET, DORSET SQUARE, N.W.





These Backs give greater Heat, with Less Coal and Less Smoke.

Directions for Use.—Place the two pieces on bottom of Grate and fasten them with the screws and put the back in either of the holes and lay it against back of Grate. Place it within two inches of Front Grate first and try it, and keep it between the backs, free from dirt. No air to pass behind the back at top; the back to lay close against the other; if not, have one made to fit.

Sizes ... ... 9 10 11 12 13 14 inches. Price from 2s. upwards.

The SANITARY RECORD says—'Most useful as an intermediary.'

THE PATENTEE IS PREPARED TO GRANT ROYALTIES FOR MAKING THE ABOVE.

DUNNACHIE'S

Patent Continuous Regenerative Gas Kiln,

FOR BURNING FIRE-BRICKS, POTTERY, ETC.,

COMPLETELY ABOLISHES SMOKE AND SAVES FROM 50 TO 75 PER CENT. IN COST OF FUEL.

IN THIS KILN ALL DIFFICULTIES IN REGARD TO MIXING AND DIFFUSION HAVE BEEN THOROUGHLY OVERCOME.

FOR PARTICULARS APPLY TO THE

GLENBOIG UNION FIRE-CLAY COMPANY, LIMITED,

4 WEST REGENT STREET, GLASGOW.

International Smoke Abatement Exhibition,

SOUTH KENSINGTON, Nov. 1881 to Feb. 1882.

The Judges have again conferred the

HIGHEST AWARD, THE SILVER MEDAL,

TO

E. H. SHORLAND,

For the Patent first-class Smoke Consuming and Warm Air Generating MANCHESTER GRATE, 'At the above Grand International Contest, in competition with the principal leading Manufacturers of the World.'
N.B.—*Vide* DAILY TELEGRAPH.

HOUSES, INFIRMARIES, HOSPITALS, SCHOOLS, or any kind of BUILDINGS,

THOROUGHLY WARMED

BY THE PATENT

MANCHESTER GRATES OR STOVES.

By their use in ground-floor rooms of houses fires in bedrooms are not required.
Thousands in use in Great Britain, Ireland, and the Continent.

To illustrate the difference in the Warming and Ventilating Power of Warm-Air Grates, please read the following:—

UNSATISFACTORY WARMING

Of the new Manchester Workhouse, Manchester, which is not fitted up with the Manchester Grates:—

Dr. Muir, H.M. Inspector of the Local Government, in his report of the above, says that the warming of the wards is very defective, as shown in the very heavy mortality from lung disease, no fewer than 320 out of 789 deaths having been due to bronchitis, consumption, and inflammation of the lungs. Additional means of warming were very urgently needed.

Vide the MANCHESTER GUARDIAN, Aug. 26th, 1881.

UNSATISFACTORY WARMING

Of the new Knightsbridge Barracks, where other than the Manchester Grates are used:—

Lieutenant-General Prendergast, H.M.S., says that it is impossible for these Barracks to be warmed by means of the grates now in use there, and that the soldiers shiver in their beds under their blankets.—*Vide* the BUILDING NEWS.

SATISFACTORY WARMING

Of the new Oldham Workhouse Infirmary, near Manchester, by means of the Manchester Grates:—

Dr. Patterson, M.D., says that there are 32 of the Manchester Grates (now at the present date increased to upwards of 80) in the above Infirmary, giving to every one concerned the utmost satisfaction; that the wards are warm all over, and absolutely free from cold draughts; that there are several wards of the following dimensions: 84 feet × 24 feet × 12 feet high, with four of the Manchester Grates in each ward, and that with the lowest fires he has never seen the temperature below 60° Fahr., and that to-day, with moderate fires, the temperature of wards was standing at 70° Fahr. at the most distant point from any Grate, and in the late severe frost, when cokes were used in the Manchester Grates the temperature got up 75° Fahr., at which point it became necessary to discontinue two of the fires.—*Vide* the FIELD, December 20th, 1879.

Illustrated Sheets and Hundreds of Testimonials on application. One just to hand says that, for the Warming of a Bedroom by the Warm Air generated by means of the Manchester Grate fixed in his Dining Room, on ground floor, is far superior to anything he had seen in his travels either in Europe or America, and thinks it a matter of regret that they are not used in every house.

In use in Palace, Jails, Churches, Billiard-Rooms, Banks, Workhouses, Mansions, Cottages, Schools, Police Cells, the Royal Observatory, Asylums, H.M.'s Government Offices, Barracks, &c. &c.

E. H. SHORLAND (late SHILLITO & SHORLAND),

Sanitary Warming and Ventilating Engineer,

THE MANCHESTER GRATE, STOVE, AND VENTILATING WORKS,

ST. GABRIEL'S, MANCHESTER.